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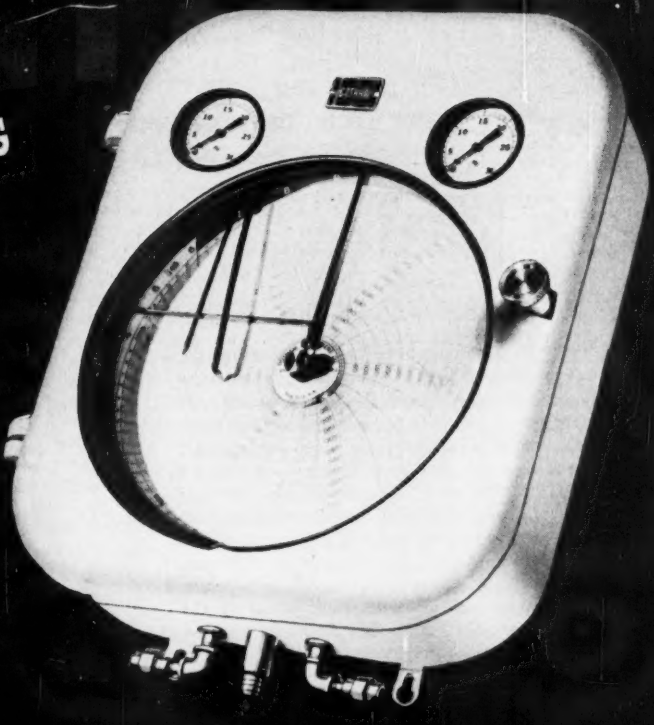

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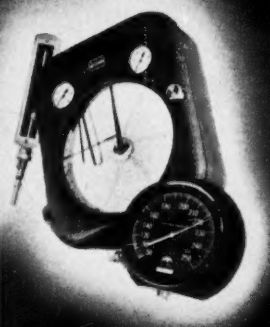

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# Instruments

Vol. 23 APRIL 1950 No. 4


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**EDITORIAL** By M. F. BEHAR

# *Automatize* Quality Control!

FOR more than a quarter-century we've preached this ideal, but not until June 1947 did we use the three-word slogan as the title of an editorial. We use it again rather soon—after less than three years—because of three recent developments in the situation:

1. Last month's talk at Pittsburgh by Charles Johnston—before a sub-section of one local section of one society, hence ordinarily fated to non-publication, but so important that we are printing it in full. Yes, it is important because its author doesn't pull his punches in giving FACTS that Top Management in all industries should ponder. He doesn't go into technical details of automatizing quality control in Final Inspection but he lays down some of the essential factors that must be recognized and appreciated in order that the purchase and installation of the automata may be approved.

2. The sermon on Instrument Engineering (officially a "technical paper") by Professors Brown and Campbell of MIT at the IRD session of the ASME's Erie meeting last September, printed in the February *Mechanical Engineering*. These eminent educators had given a similar talk last summer before a group of engineering professors. The gist of this sermon is that processes should be modernized by automatic-control systems with quality-measuring primary elements—instead of elements responding to pressure, temperature, pH, etc.—commanding the whole process. (Same idea as in the last four paragraphs on page 531 of the June 1947 issue of *Instruments*, which wasn't the first disclosure: the "direct quality-control" concept dates back to the team-work of some process engineers, instrument-company men and process-equipment builders in the nineteen-twenties.) They also proposed two new names, "System Instrument Engineering" and "System Engineering," for the old branch of Instrumentation called "Application Engineering" in the nineteen-twenties and thirties.

3. The strange and alarming inferiority complex from which some Instrument Men seem to be suffering—in some cases the very men who were justly proud of Instrumentation in general and of their own automatic-control jobs in particular. Only recently—the last month or so—they've begun to talk among themselves as if "Cybernetics" and "System Engineering" and "Servomechanism Technique" and "Coordinated Automatic Control" and "The Manless Factory"—and so on—represented ideas or ideals or methods or philosophies or practical everyday jobs different from those that rightly belong in Instrumentation.

We comment first on No. 3:

Shame on you!

Yes, you, the men we most admire because your everyday jobs do more for the health of our American industrial civilization than all the pronouncements of all the politicians and . . . editors! Yes, you, our dearest friends, who for years have been doing your best to automatize quality control and thereby make better and better products (absolutely), sold at lower and lower prices (relatively)! Yes you good guys—great guys!—who don't get national publicity—who shun personal publicity for your useful achievements in applying the various branches of the Science of Instrumentation—achievements that have brought to our beloved nation more per-capita real buying power, more leisure, and less repetitive drudgery, than anywhere else on earth!

Where would we Americans be without our high—and constantly-rising—productivity? You know the answer: the labor-content of every loaf of bread, of every pair of shoes, of every piece of furniture, would be so high that most necessities would be luxuries. An automobile without Instrumentation in the automobile industry would cost fifty thousand dollars. Ten or twelve hours a day would be spent in repetitive drudgery by most of us—including teen-agers now in high schools and the millions in colleges and universities (most of which schools would be in their Nineteenth Century stages of evolution). Well, this high and constantly-rising productivity is largely the result of your work in applying the Science of Instrumentation. Don't talk and act as if you were ashamed of it!

As for No. 2: Brown and Campbell—and Wiener and others—at MIT and perhaps in other great centers of higher education, they have a perfect right to coin new names to denote their own brilliant accomplishments. So have Instrument Men, or Instrumenticians, or Instrument Engineers, a perfect right to keep on considering Automatic Control—as it has been considered since 1924—to be one aspect of Instrumentation, which is the Science of Measurement AND Control.

A few years ago a physicist wrote an article for a scientific journal, stating that there ought to be a science of instruments and he proposed (*again*, unknowingly) the name "Instrumentology." Brown and Campbell *have* made brilliant mathematical contributions *of their own* to the control branch of Instrumentation. Unfortunately, until recently they were isolated from the stream of instrument progress. When we first met them during the war, they made no effort to conceal their scorn of "hardware men and gadgetry." Here's hoping that they'll be satisfied with the laurels they won by their brilliant wartime work plus the new laurels they will win by their other *original* contributions!

Let no reader infer that we have it in for MIT professors. All of us "hardware" or "plumbing" men owe a great debt to Hazen, Brown, Campbell and others of the Servomechanism Lab, to Draper and others of the Instrumentation and Aero Labs, to Harrison and others of Physics, to Gray and others of Electrical Engineering, and to many other MIT intellectual giants—and to their colleagues in other lofty institutions!

Let no reader infer that the editor lacks devotion to colleges and universities. We've not only sung the love of our own engineering alma mater at alumni reunions but we've given her a percent of our annual earnings which is many times the national average. We've given to other glorious institutions and among our proudest memories are the lectures we were invited to give at MIT and other centers of higher learning. We *know* that in math and other studies we're a pygmy among these giants; but that has never given us an inferiority complex: on the contrary, this awareness of our place has stimulated us, since graduation, to continually contribute our own specialized two cents' worth to science and technology. No practical Instrument Man need envy the gifted intellectual giants: envy is a sin and only the scales of God Almighty can weigh the relative worth of each individual toiler in His vineyard!

Let no reader infer that we believe highbrows to be high-hat! Professors Brown and Campbell aren't snobs: it's their hard luck that they waited so long to mingle with "plumbers." And the greatest instrument scientist of them all, Charles Stark Draper, head of the MIT Instrumentation Lab, winner of a string of high honors, is the most unassuming regular guy who ever lifted elbows with "plumbers"! It was Stark Draper who told a group of Instrument Men that aviation began in a bicycle-repair shop run by two mechanics who, at the time, couldn't spell "aerodynamics" and knew no math beyond arithmetic. Warm-hearted Chuck Draper has always loved to mingle with "plumbers" and has always praised to the skies their contributions to the advancement of Science.

Automatic direct quality control, defined two decades ago by Instrument Men, blueprinted more recently by Instrument Men, is modern Management's responsibility. Fortunately, today's forward-looking top managers appreciate the possibilities of Instrumentation . . . and the abilities of their own Instrument Men!

## Ninety-nine

IN THIS month's "New Instruments" Department, there are no fewer than ninety-nine items—setting a new record (previous record, ninety-six). Some of the items announce new "series" or "lines," each consisting of a number of sizes or styles of a new device; so that the total number of new products reported in this issue runs into the hundreds.

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☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆

☆ The following sixteen entries received Honorable Mentions in *Instruments'* contest. The theme was "Instruments Cut Costs." ☆

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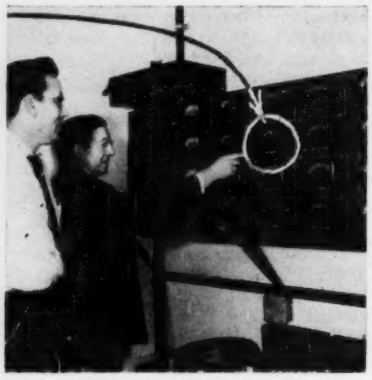


# QUALITY CONTROL INDICATOR CUTS PRODUCTION COSTS

**By T. R. HAND, Special Products Division (Schenectady) and R. C. MILES, Quality Control Engineer (Erie Works), General Electric Co.**

IMAGINE cruising down the highway at fifty miles an hour with only your rear-view mirror as a guide. Control of quality in industry has been in a similar position: looking back at production troubles, spotting them only after hours' or days' delay.

Statistical quality control offers a method of showing when abnormal trouble arises. Unfortunately, it has been limited in effectiveness by the time delay and the costly man-hours needed in collecting and using the information.

But a new management tool—the Quality Control Indicator—shows instantly the actual reject level on a production line. Supervisors can now spot trouble immediately and take prompt action to reduce scrap and rework expense. The device automatically performs the function of statistical quality control charts instantaneously and without the necessity of additional personnel. An average reduction in rejects of 60 percent was realized over the previous statistical quality control method after installing the Quality Control Indicator on a refrigerator compressor assembly line at General Electric's Erie Works.

For the five characteristics monitored on this assembly line, a saving of $13,000 resulted the first year due to reduced scrap and rework expense. Now, the other nine production lines monitoring over 55 characteristics have been equipped with the Quality Control Indicator. Substantial cost reductions are already developing on these other lines.

On any production line, a supervisor may wish to inspect his product for various characteristics such as power consumption, noise level, color match, etc. The Quality Control Indicator counts the total number of units inspected, and also the number of units rejected, for a certain characteristic, —such as color match. When a unit is rejected for a certain characteristic, the inspector on the line pushes a button. The circuit automatically makes a change in the actual reject level indication on a Quality Control Indicator located in the supervisor's office.

If the reject level is below the allowable limit, the needle will be in the green or satisfactory portion of the scale. If the reject level on the line is above the allowable limit the needle will be in the red portion indicating an abnormal number of rejects.

The accompanying pictures, taken at the pilot installation, show how the Quality Control Indicator spots abnormal trouble, and makes possible prompt corrective action.

No. 1. In this booth the inspector tests compressor assemblies for 10 characteristics. When a reject occurs the proper reject button (on wall) is pushed, giving a signal to the Quality Control Indicator.

No. 2. Quality Control Indicator located in supervisor's office shows reject level for each characteristic. Supervisor points out to his assistant the high rejects present on one test.

No. 3. Assistant gets several rejected assemblies from the inspector in the test booth.

No. 4. Rejected assemblies are given careful check by a "trouble-shooter." He believes trouble lies with certain assembly machine.

No. 5. Upon investigation, this machine is found to have a worn die. The operator replaces this die.

No. 6. In a few minutes—trouble spotted, action taken, scrap and rework expense avoided.

# AUTOMATIC WATER SOFTENER

By J. A. HARTNETT, Honeywell-Brown Limited, Greenford, Middlesex, England

IN WATER-SOFTENING apparatus it is periodically necessary to effect regeneration by carrying out a cycle of operations, in each of which a different flow of liquid is established and maintained for an appropriate length of time. In many water softening installations now in use, the opening and closing of the requisite valves is effected manually. Automatically-controlled softeners are available, but the control apparatus is not suitable for use in connection with the smaller water-softening installations, whether for household or commercial use, on account of the high cost.

The apparatus for controlling the flow of liquids consists of eight single-seated valves which are operated by cams mounted on a common shaft. An M204 motor (ex Minneapolis Honeywell), which has been modified to a four-position motor, rotates the shaft through four positions in each of which selected valves are operated by cams.

The automatic-control gear causes the motor to rotate the cam shaft from one operative position to the other.

The valves are of the single-seated type, spring-operated to one position, and moved to the other position by the operating cam.

The control gear is arranged to cause the motor to rotate the camshaft to each of its operating positions successively, allowing the shaft to remain in each position for a predetermined length of time until the shaft has returned to its starting position.

The periodic energization of the control device may be effected automatically by a time switch so that, for example, the cycle will be carried out at a fixed time each day, or to the quantity of liquid which has flowed through a given part of the apparatus since the control device was last energized, or to some other condition existing in the apparatus controlled.

The water-softening apparatus comprises softener proper, a saturator tank and an ejector. They are connected to one another and to a hard water inlet, a soft water outlet and drain pipes, through pipes which are controlled by the eight cam operated valves.

Referring to the attached piping and wiring diagrams, when the apparatus is used for water softening, valves A and B are opened, and the other cam operated valves are closed. Hard water from the inlet 9 then passes through valve A to the softener, and the softened water flows through valve B to the outlet pipe 10.

To effect regeneration of the softener, three different liquid flows are successively established. To backwash the softener, valves C and D are opened and the other cam operated valves closed. Inlet pipe 9 is then connected through valve C to the normal outlet of the softener, and the normal inlet of the softener is connected through valve D to the drain pipe 11. A flow disk 16, formed with an orifice of limited size, reduces the flow of water to a predetermined rate.

To effect the regenerating operation proper, valves E, F, F1 and G are opened and the other cam controlled valves closed. Water from the inlet pipe 9 then flows through valve E to the ejector 8 and thence through valve G to the top of the softener. The softener outlet is connected through valves F and F1 to a regulating valve 16, and thence to the drain pipe 11. During this operation the ejector draws brine from the saturator tank 7 through back pressure valve 17, and make up water flows into that tank.

To rinse the regenerated softener, valves A and F1 are opened and the other cam controlled valves closed. Water from the inlet pipe 9 then flows through valve A to the softener inlet, and the softener outlet is connected through valve F1, and a flow disk 18 to the regulating valve 16 and then to the drain 11. It will be seen that valves F and F1 both serve to connect the softener outlet to drain, but the flow disk 18 limits the rate of flow of liquid when valve F1 only is in use.

The cam shaft has four operating positions, disposed at angles of 90 degrees to one another. As will be appreciated from the above description of the liquid flow circuits, the shape and arrangement of the several cams is such that in each one operating position, valves A and B are opened and, in the next position, valves C and D are opened; and, in the third position, valves E, F, F1 and G are opened; and, in the fourth position, valves A and F1 are opened (the remaining valves being closed in each case).

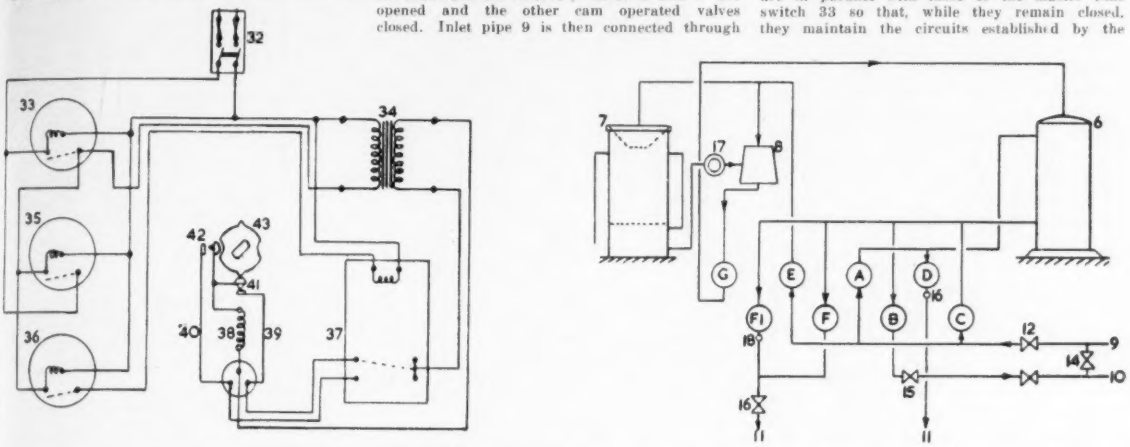
The electrical hook-up for the control gear is also shown diagramatically. The electric supply is connected to energizing winding of a master time switch. This master time switch is arranged to close its contacts at a given time each day and to re-open them after a period of, say, half an hour. As shown by the circuit diagram, closure of the contacts of the master time switch operated to connect the supply to the primary of the transformer and to energize the windings of the synchronous time switch 35, and the operating time switch 36. The synchronising time switch 35 is arranged to close its contacts for a short period after energization, and to hold them closed for the remainder of a period of one hour.

The contacts of the synchronising time switch are in parallel with those of the master time switch 33 so that, while they remain closed, they maintain the circuits established by the master time switch, even after the latter has reopened its contacts. The operating time switch 36 is arranged to close its contacts shortly after energization, and to hold them closed for the period necessary to effect back washing, which may be three minutes. The contacts then remain open for the period necessary to effect the regenerating operation proper, which may be three and a half minutes. They are then again closed and are held closed for the period required to effect rinsing, which may be thirty-five minutes, after which they are again re-opened.

Switches 35 and 36 continue to run, until one hour after its original energization. The synchronising switch opens its contacts, thereby breaking the circuits of its own energizing winding and that of the operating time switch 36. All the time switches are now restored to their original condition in readiness for the next operation of the master switch 33.

The master time switch 33, which serves to initiate the regenerating cycle at a fixed time each day, could be replaced by a switch operated by a water meter responsive to the flow of liquid through the softener. This water meter was actually used in the softener shown in the attached photograph. With this arrangement regeneration is effected when a pre-determined quantity of water has passed through the apparatus.

This automatic-control system is not limited to the particular arrangement described above, but may have application other than water softeners.




# IMPROVISED AIR-PRESSURE BOOSTER

By V. A. RIGGIO, 20 Green Acres, St. Louis, Mo.

WHEN in need of an air booster for use between an air-operated controller and a diaphragm valve with a large diaphragm capacity or extra long air lines, I've removed the top spring from a Moore differential-pressure regulator and, because this regulator has two diaphragms with a relief valve, it is a very good air booster with an enormous volume. After running various tests we found it accurate to 0.5 inch water column. We have had about two dozen in use for more than two years without trouble.

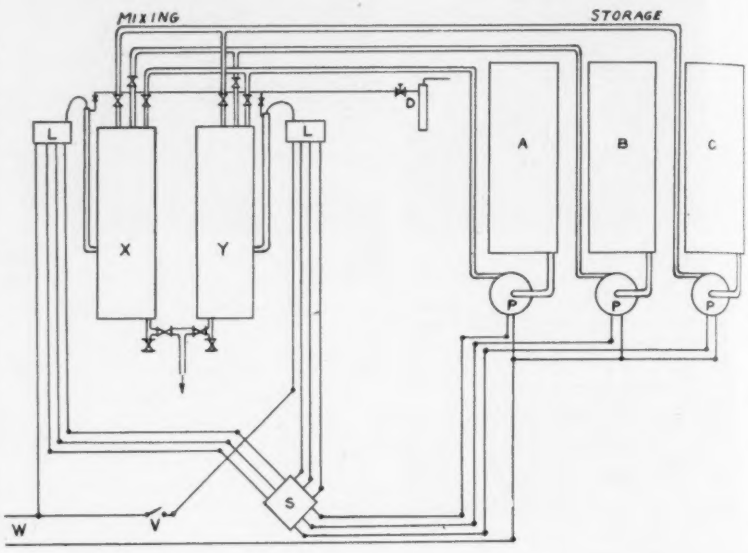
# FLUID PROPORTIONING CUTS COSTS

By HENRY I. NORTON, Needham 92, Mass.

ALTHOUGH special equipment for fluid proportioning is on the market for several applications, the use of the time-proved bubble-pipe to operate controls offers high accuracy at low cost with simplicity and trouble-free operation. By using electrically-operated valves in place of those hand-operated in the diagram, mixing is reduced to a push button procedure. By varying the size of tanks and pumps, this basic system can be applied to very large or very small units. It is not confined to two or three fluids, but can take care of more by adding to the bubble-pipe control to operate the added pumps.

Referring to the diagram, the system consists of storage tanks (A-B-C) for the fluids to be mixed. Each fluid has a transfer pump that is connected to two mixing tanks (X-Y). In each pump line there are two valves so that the flow can be directed to the desired tank. Two tanks are usually needed so that while one is supplying the process, the other is being filled. When the operation is not 24 hours per day, as in paper mills, it might be possible to use one mixing tank by setting a time starting switch to come on before the plant opened so the mixing could take place during the night or non-operative period. Each mixing tank is equipped with a bubble pipe, which is merely a pipe through the side of the tank or one projecting down through the top. For this service, the compressed air line is filtered and reduced in pressure (D) as a safeguard to the elastic elements in the level switches (L) which control the pumps. If no compressed air is available, a diaphragm bell (Foxboro) can be used instead, with satisfactory results as long as the connections, etc., are tight. The electric power line (W) is 110-volts single-phase which can be used to operate small centrifugal pumps (Eastern Industries, Inc.) direct or through magnetic switches for 3-phase motor-driven large pumps. Starting switch V is used to start the cycle and is opened before changing selector switch S from one tank to the other.

The operation of one cycle would start by checking the valves at the bottom of mixing tank X to be sure they are closed, then closing the pump line valves over mixing tank Y and opening those over mixing tank X. After setting selector switch S to the level control on mixing tank X, the proportions will start as soon as switch Y is closed. Electrically-operated valves would entirely eliminate the manual operations, further reducing operator time and decreasing the possible error caused from forgetting valves. As soon as switch V is closed, the pump for storage tank A starts pumping into mixing tank X until the predetermined level is reached. At the control point, the pump for storage tank A is shut off and the pump for storage tank B is started. As the level reaches the second control point, the pump for storage tank B is shut off and the pump for storage tank C is started. As the level reaches the third control point, the pump for storage tank C is shut off and the mixture is complete. Repeating the cycle for mixing tank Y would be identical with the double cycle being repeated indefinitely or revised by changing the control points.




The addition of a two-record recorder in the process room, with switches S and V for a system with electrically-operated valves, would entirely eliminate an operator for the mixing by having the process operator make batches as required. The simplicity of the system and equipment offers trouble-free operation and no maintenance problems. The elimination of the mixing operation will permit an increase in wages for the process operator as well as more uniform batches that will result in better quality and customer relations. Repeat sales are as important as new ones and, to some, more important.

# AUTOMATIC X-Y COORDINATE MILLIVOLT RECORDER

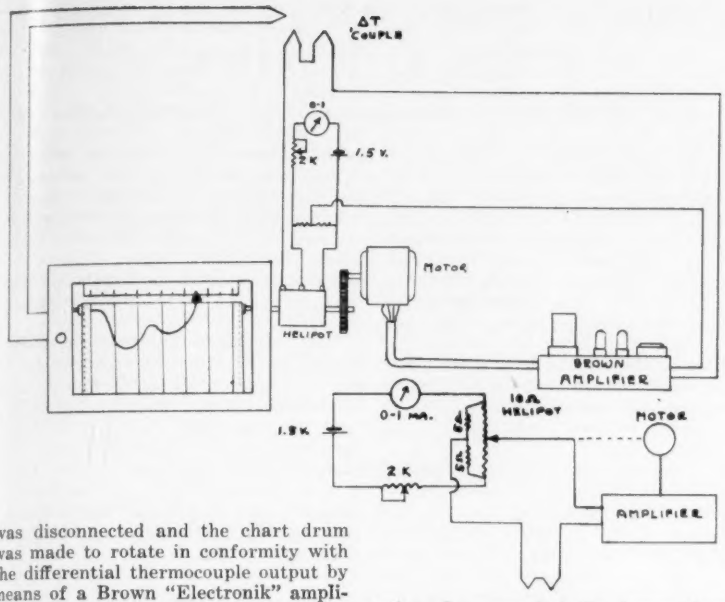
By PHILIP W. DEWEY, Whiting Research Lab., Standard Oil Co., Whiting, Ind.

CONSTRUCTION of an automatic X-Y coordinate millivolt recorder was undertaken, primarily, to minimize time and labor in performing differential thermal analysis. The experimental technique in differential thermal analysis involves subjecting a given quantity of material under observation and an equal quantity of a known or reference material to a progressive heating or cooling treatment. The differential temperature between the known and unknown material is plotted against the actual temperature during the heating or cooling treatment. The resulting plot is particularly significant for the evaluation of chemical compositions and transition phenomena for materials that show heats of reaction.

In the past, in performing differential thermal analysis it has been customary to record the actual and differential temperatures separately and then cross-plot these data. This procedure is very tedious when many samples have to be analyzed.

My recorder system automatically plots the differential temperature as a function of the actual temperature, thus giving the desired temperature cross-plot directly in the form these data are conventionally plotted for the final interpretation. This recorder has been in continuous use for the past ten months in determining structure of catalysts. Its use has enabled detection of transitions with greater completeness and certainty than heretofore. Performance of the recorder has been exceptionally reliable. Substantial labor savings have resulted.

Any conventional strip-chart temperature recorder may be used as the basic instrument for recording the actual temperature. In this particular case a Brown mechanical strip-chart potentiometer with a range of 0-2000 F. was employed. The usual chart drive




was disconnected and the chart drum was made to rotate in conformity with the differential thermocouple output by means of a Brown "Electronik" amplifier and its associated balancing motor with suitable gearing. The differential emf. slidewire consisted of a Beckman (10-turn 10-ohm) "Helipot" shunted by a center-tapped resistor to enable proper directional operation in accordance with polarity. The resistance values, shown in Fig. 1, were chosen to give a span of plus or minus 2.5 millivolts. The total span of 5 millivolts is distributed over ten chart drum revolutions or approximately 60 inches of chart. A slidewire current of about one milliampere was used, since in dealing with low millivolt spans it is better to use higher resistance values and lower slidewire currents (it is difficult to make extremely low resistances which will come out correctly when soldered into the measuring circuit). The slidewire current is maintained at a constant value by visual observation of a 0-1 milliammeter and manual adjustment of the variable resistance. Final calibration of the differential emf. span is accomplished by adjusting the slidewire current to the exact value to make the one-tenth millivolt chart drum movements line up with the horizontal chart lines. The current is then kept at this value. It has been found that one daily standardization suffices.

The utility of this recorder is not limited to differential thermal analysis. Any two variables which can be converted to variable emf's can be cross-plotted if they fall within the range of the instrument. One example would be the plotting of fractionating column overhead temperature against volumetric take-off. Other applications would be engine speed against fuel flow, stress-strain plots in materials testing, and hysteresis loop plotting.

A schematic sketch of the recorder system is shown in Fig. 1. A gear ratio of 4 to 1 between the differential balancing motor and chart drum was found adequate. However, this can be changed readily to give any desired balancing action. In operation the lower chart re-roll spindle is not used. The end of the chart is slightly weighted and allowed to hang down as far as necessary. A supply of chart is also looped down in back of the chart drum and a chart roll tube placed in the loop. This insures keeping the chart on the chart drum sprockets.

It is obvious that the element of time does not enter into the curve plotted by this recorder. In differential thermal analysis it has been found desirable to have a time record of actual temperature heating schedule. The arrangement shown in Fig. 2 was installed for this purpose. A small emf. (about 0.01 millivolt) is introduced into the differential thermocouple circuit at any desired time interval (5 minutes in this case). The time record shows up in the form of a small pip on the curve. Any electrical timer can be used which will make contact for about one second at the chosen time interval. The resistor R1 can actually be a few inches of the thermocouple wire itself. The height of the pip is determined by the setting of R2 which governs the current through R1 and consequently the injected emf.

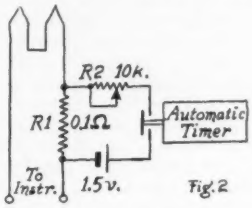


Fig. 2

# COMPARED WITH MANUAL METHODS, INSTRUMENTS CUT COSTS

By GENE WOODMAN, Rt. 2, Box 93, Vicksburg, Miss.*

TO THE writer (by nature a gadgeteer, as well as by profession) the statement that Instruments Cut Costs is as apparent a truth as it is to observe that there is light when the sun is up. However, during recent years of supplying instruments for various users, there have been numerous contacts with other individuals less inclined to accept this truth so readily; hence the need for sounding this theme becomes the more obvious.

Instruments are expensive; labor is cheap. Static economy would appear to favor labor. But add the element of time and the picture soon reverses; dynamic economy must work out in favor of instrumentation. Take the simplest of cases, for example, such as the counting of packages moving along a conveyor belt. Obviously, one can hire a man for a day to count these packages much cheaper than one can procure and install a counting instrument such as a photo-cell and electric tally. But for two days work the man's pay is doubled, while the instrument cost is the same. Extend this in time—one week, one month, one year—and eventually the continuing labor cost will equal the intial instrument cost. Beyond this point in time the instrument cost is less than the total labor cost with cumulative savings as time goes on.

The basic illustration just given may be applied to any instrumentation vs. manual argument, no matter how complex, and the result will bear out the immutability of this dynamic economy. Obviously, it would require a great length of time to attain economic satisfaction for an instrument costing tens of thousands of dollars to replace an inexpensive laborer, but even this situation would be resolved in time. As the cost of the instrument is lowered, and as one instrument is used to replace several men, the time for economic justification becomes proportionally shorter.

But this is not the entire story, nor even the meat of the story. Our laborer counting packages gets tired or careless, occasionally, and his count is in error. Or perhaps he is absent one day and we must secure and instruct another counter. Not so our electric tally: with the necessary minimum of preventive maintenance and attention this unit goes on counting package after package, fast or slow, day in and day

* EDITOR'S NOTE.—This is the only address we had until, after the usual notification, etc., we received a letter from Lt-Col. R. D. King, Director, Waterways Experiment Station, Corps of Engineers, U. S. Army, informing us that Mr. Eugene H. Woodman is Chief of the Station's Instrumentation Branch and "has played an important part in the development of various unique instruments used in our work."—MFB

out, ever ready, willing, and accurate. Furthermore, complicate the problem as you please. Add green packages to be counted, yellow ones not to be counted; this will further fatigue the laborer, but have no effect whatsoever on the instrument's operation. Going further, count packages of a certain size or weight, and omit others from the count; the laborer's task is greatly slowed, perhaps to the point of requiring two or more laborers to maintain the pace, while with simple alterations our instrument counts merrily on. Finally, suppose packages are to be counted at irregular intervals of one-half hour two or three times a day; our laborers must be rounded up or be paid for sitting by idly the rest of the day and immediately get into the spirit of counting, while our little instrument is always ready at the flip of a switch.

Again, it is desired to emphasize that complex instrumentation is even more prone to operational as well as economic justification. The more difficult or precise the process for which instruments are proposed in lieu of manual operation, the greater the likelihood of securing more satisfactory control with instruments than by manipulation. Accuracy of performance and accuracy of repetition can be provided to any desired degree of precision by instrument assemblies as simple or as complex as may be dictated by the process at hand with results comparable to or exceeding results to be obtained by manual operation, regardless of cost, and, in many cases, utterly beyond manual possibilities. Furthermore, synchronization and coordination present no problems whatsoever to instrumentation, whether there be two, ten, or one hundred units involved; let this be contrasted with the increasingly difficult or even impossible task of likewise coordinating the activities of two, ten, or one hundred operators controlling manual operations in a process.

To summarize, in any comparison of manual vs. instrument control of processes it must be realized that any degree of precision attainable in manual operation can be duplicated or improved upon by suitable instrumentation methods and that certain conditions impossible of achievement by manual means can be met by suitable instrumentation. This, in turn, points to sometimes intangible but nevertheless substantial savings in costs due to adequate accuracy of operation, accuracy of repetition, and synchronization of control provided by instrumentation methods. Furthermore, there are very tangible savings in costs based on the dynamic economy of comparison between manual and instrument operational costs in which the sharply-rising curve of continuing manual operation must in due time intersect the nearly-flat curve of instrument operation. On the basis of the foregoing reasoning, one must reach the unassailable conclusion that certainly Instruments Cut Costs.

# "DOWN-TIME" (AND RESULTANT COSTS) CUT DOWN

By VICTOR STUART, Knopf Instrument Co., Jersey City, N. J.

IN CONSIDERING the subject "Instruments Cut Costs," the one instrument most in my mind is the "Pe Ka Travelog," known as "Micky" here in New Jersey. Travelogs have a unique way of dropping "down time" on industrial machines to a bare minimum. They are being used on packaging machines, fork trucks, rolling mills, and so forth.

Commercial trucks are where they have really proved their worth. Travelogs are the essence of simplicity in recording method, installation and reading.

A Travelog can save the owner of one truck $750 per year—or more. Multiply this by five or six (or one hundred) trucks to realize the staggering amount of money misspent each year by the various owners of vehicles.

The same holds true for industrial machines. "Down time" can be cut to a bare minimum after the installation of the Travelog. In this case, feet, pieces, revolutions, yards, etc. can be accurately counted and permanently recorded for future reference, or present action.

The Travelog is a permanent supervisor with no absences or vacations—and the total cost is no more than the salary of a supervisor for one week.

In the final analysis, the controlling member of your truck or machine is the controlling factor of your profits. Production engineers have come to realize this, and are using the Travelogs to great advantage to boost production, sales and profits.

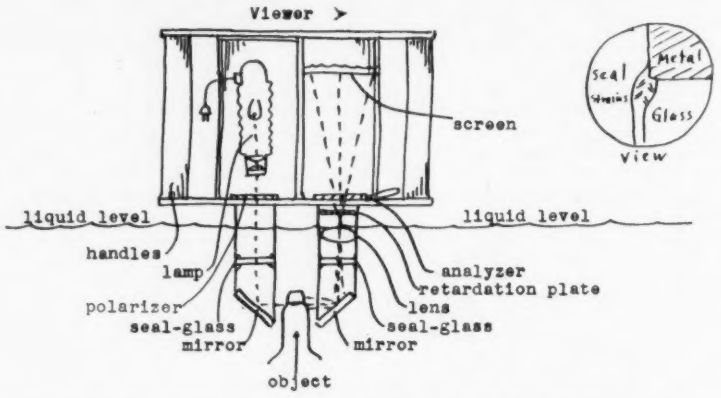
# INSPECTION POLARISCOPE FOR DRY AND IMMERSED PARTS

By HERMAN RUEGER, Lancaster, Penna.

USE of polariscopes to detect strain patterns in transparent objects is widely practiced with dry specimens. Immersion tanks are often filled with liquids (having nearly the same indices of refraction as the glass or other transparent objects to be examined) so that projected images of the objects can be made to reveal their inner shapes and flaws, for study without destroying the specimens. A combination in one instrument of a projector and a polariscope for both dry and immersed object study, the entire instrument being portable, is not often attempted.

Such an instrument was built by the writer and used successfully to examine shadow projections of glass-to-metal seals, and the strain patterns incurred in their manufacture as parts of large vaccum tubes, which could not be so viewed with any known instruments.

The construction (see accompanying sketch) is quite simple and, because all of the accessories are self-contained, the instrument is easy to use. The metal bowls of the tubes, with their "chimneys" of glass near their centers, were immersed in suitable liquid, and filled with the same, so that both sides of the glass to be examined were below the surfaces. The instrument lamp was switched on, and the two legs lowered into the same liquid. The beam of light passed through the lamp condensers, and the polarizing disk, through the glass-sealed port, to the mirror in the first leg; thence out through the liquid, through the glass specimen, through more liquid to the mirror in the second leg and up through the glass sealing port and the adjacent magnifying lens, through the quarter-wave retardation plate and the rotatable analyzer disk; hence through the projection tube to the



ground glass (sand-blasted plastic) serving as a resolution screen. The sealing ports were placed above the mirrors for compactness, and the immersion did not affect the aluminum-first-surfaced mirrors.

For simplicity the focus was fixed so that any object midway between the legs of the instrument would be focused upon the screen. A collar acting as a viewing shade improved visability in well-lighted rooms. The two handles were designed to serve two functions, acting also as structural supports.

The analyzer disk was mounted in a rotatable ring with an extending lever arm which was readily moved by two fingers, so that for mere shadow projection a yellowish light was used, whereas for strain detection the lever was moved until the familiar purplish tint of the retardation plate was evident. Strains showed in bright green-blue and orange-red colors. The magnification (about 3 to 5 x) made the images very clear.

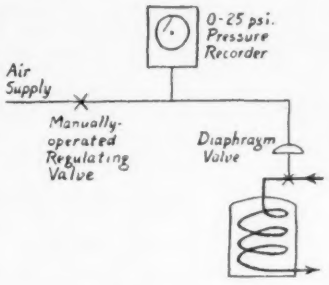
The only difficulty experienced was with the sealing plates. When these leaked, black shadows (bubbles) interrupted the view. Rubber rings used as gaskets solved the leakage problems, and merely shaking the instrument after immersion was a simple means of dispelling any bubbles trapped below the thin rims of the sealing-glass ports.

In addition to its usefulness as a self-contained portable instrument, this device freed the larger polariscopes for other uses of more conventional nature.

# VALVE-SIZING FOR INDIVIDUAL APPLICATIONS

By V. A. RIGGIO, 20 Green Acres, St. Louis, Mo.

ON many installations it is often impossible to determine the valve size to fit a control problem. By means of the scheme hereby described, we are able to determine approximately what size valve is needed. The scheme involves recording the air pressures to a valve of good characteristics over a period of time. This is a great help on glass-lined reactors. By noting batch temperature with corresponding diaphragm pressure, it can be decided approximately what valve size is needed.




# CONTROLLING COSTS IN THE PRODUCTION AND DISTRIBUTION OF UTILITY FLUIDS

By ROBERT L. GALLEY, North American Aviation, Inc., Los Angeles, Calif.

EVERY power man knows about the tremendous strides made in the use of measuring instruments and automatic-control systems in the production and distribution of utilities—steam, hot water, refrigeration, compressed air, and the various water services used by the modern industrial plant. Volumes have been written about hundreds of instrument applications with which we are all familiar. From the first instrument used in the power house—the ordinary steam pressure gage—to the latest complicated system of coordinated boiler controls, power folk can trace the evolutionary (and revolutionary) growth of instrumentation. Perhaps no other segment of industrial activity has come to lean so heavily on instrumentation; power men are thoroughly "sold"!

It is a less appreciated fact, though, that the installation of measuring instruments and automatic controllers in itself does not guarantee efficiency and low costs. The stories told by the charts must be constantly studied to keep tabs on possible losses. This task usually falls to the superintendant, who delegates the actual bookkeeping and detail work to the "results" or "efficiency" staff. It is their function to translate the chart records into facts and figures and to plot the trend of the loads and the performance of the various component units.

There are two spheres of operation with which the power man is, or should be, concerned. First, of course, is the efficient conversion of fuel into steam or electric power, and the most economical transformation of that power into pumped, heated, and cooled fluid-streams. The other sphere of operation is external to the power area itself, and concerns the wasteless utilization of these services. Fortunate, indeed, is the industrial organization that recognizes the necessity for such bilateral responsibility.

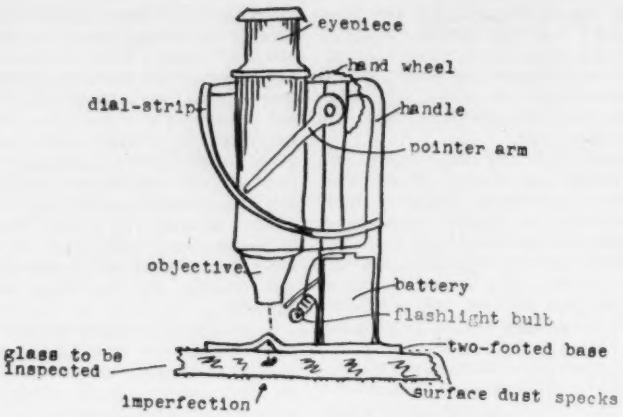
Probably the most important single type of instrument used in the tracking down of truant fluids is the common flowmeter. Where these are strategically located and intelligently used throughout the plant, it is possible not only to properly charge each department and process unit its fair and proportionate cost of the distributed utilities, but they also provide a basis for (1) scheduling preventive maintenance and "turn-arounds," (2) rehabilitating or replacing inefficient equipment, and (3) tracing and correcting wasteful processes.

Case histories would produce countless factual data bearing out the wisdom of installing *and making use of* a comprehensive and well-integrated network of distribution flowmeters. I used italics because all too often a hind-sighted plant manager has reduced the effectiveness of such an investment by refusing the needed expert personnel and maintenance facilities to an under-staffed and poorly-equipped instrument shop. Surely, the original investment in flowmeters was planned with the thought that they would be kept in such a state of good health that the intelligence they can furnish when properly cared for would be available, and would be nominally accurate.

Another mistake noticed when making plant surveys is that we often fail to recognize the importance of moving a flowmeter from its original place of installation to a more strategic metering point after intra-departmental charges render the flowmeter readings misleading (although not inaccurate). Too often the flowmeter is abandoned or removed entirely when its readings become meaningless.

In a large manufacturing plant the usual system followed in allocating utility costs is to split up the total cost of producing and distributing each individual utility, such as steam, among the consumers according to the metered percentages. Distribution losses (i.e. line condensation along main steam trunk-lines) are thus automatically proportioned, also.

However, in small plants it often doesn't pay to allocate power costs by separately metering each individual utility. Meter installations should justify their existence by amortizing themselves within a reasonable time in terms of wastefulness discovered *and eradicated.* It then becomes smart, in a medium-size or small plant, to attempt an over-all distributed cost breakdown on a single unit basis. That is, by converting all energy consumed to a Btu. basis. This is easily accomplished in the case of steam, heated and refrigerated water, etc., by using heat values and, where electric energy is consumed, by converting kilowatt-hours to Btu's. Most industrial processes lend themselves easily to intelligent estimation of power consumption by a temporary metering installation. With the average rate of utility consumption thus established by test, a fair estimate can be set up and departmental charges prorated on a time basis.




# FLAW LOCATOR FOR TRANSPARENT PARTS

By HERMAN RUEGER, Lancaster, Penna.

OFTEN the need arises to inspect transparent articles to locate and measure flaws in the material, as for instance stones and bubbles in glass bulbs used for television work. When the bulbs prevent the approach from more than one side of the glass, usually the outside, a real problem is faced. By the use of certain known laws of refraction of light rays, and the use of known instruments combined in a workable unit, such problems can readily be solved. An instrument built by the writer is described briefly herein.

According to the refractive index of a material, such as glass or transparent plastic sheeting, light is bent when entering the material from an angle. The same "slowing-up" of the wave front causes an apparent image which seems to be closer to the viewer that it actually is. The penny at the bottom of the cup seems to be nearer after water is poured over it, etc. To measure part air, part water, or part glass medium for any total light path would result in consultation of various charts and tables of correction, always bothersome. Hence the need for an instrument which would give the correct location without other reference material. This need was met as follows:

A microscope barrel, with objective and eyepiece, was mounted on a two-legged stand, one hand-wheel replaced with a pointer-arm, a sector-strip dial piece affixed, and a self-contained flashlight bulb and battery included. The depth of field of the 150x magnification employed was very shallow, and this fact permitted focusing upon otherwise unnoticed objects, as for instance, the dust specks upon the near surface of a piece of glass (however clean it appeared, the tiny "stars" are always there). Thence, looking through the glass, dust specks on the far side can also be seen clearly. The pointer-arm is set at zero for the first reading (one end of the dial strip) and the position noted at the second position. The swing shows the "apparent" distance, through air and glass, of the glass thickness. Similarly, stones imbedded in the glass are first measured as to their spacing below the near surface, or from the far surface, the focusing being usually within a few thousandths of an inch, owing to the shallow depth of field. When known thicknesses of glass, such as for instance slides or cover plates, are measured beforehand, and their thicknesses marked on the dial strip, calibration between such marks is an easy matter. The dial strip is not otherwise calibrated, so as to allow one's own marks for each kind of glass viewed. The difference between glasses is very slight, and several observers will obtain practically the same readings, by merely focusing sharply on the part to be noted. The built-in light assures amply the illumination in dark places, a constant angle of light, and uniformity at all times. Built of light alloy, the entire instrument was light, and could be used with one hand for any flat or curved surfaces with equal facility.

The construction in general is shown herewith. The same principles can be employed in instruments having many kinds of legs, or supports, according to the forms of the objects to be inspected. While it is intended mainly for inspection of transparent materials, the instrument functions equally well for hole-depth and inaccessible ledge depth measurements of opaque objects.

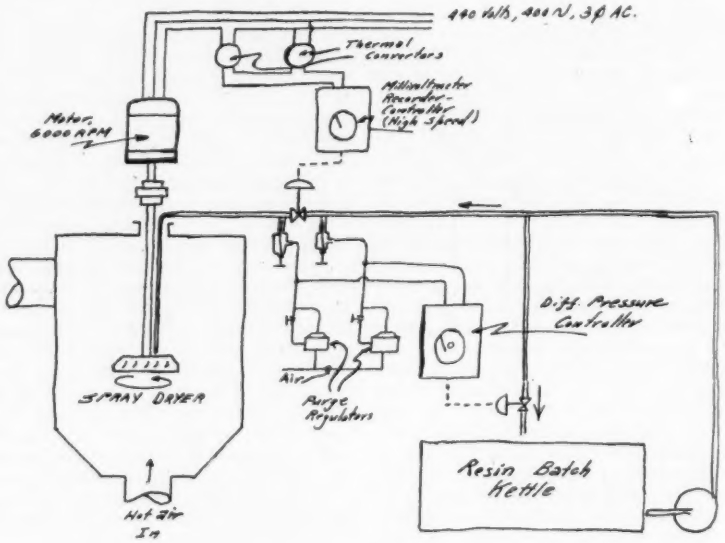
# CONTROL INSTALLATION PAYS FOR ITSELF IN ONE WEEK

By A. L. CHAPLIN, Proctor, West Virginia

BEFORE AUTOMATIC CONTROL

SEVERAL years ago a plastics manufacturing plant was producing a resinous material by rapidly drying a viscous solution in a spray drier. The high-speed wheel (6000 rpm.) broke up the syrup into a fine mist inside a drying chamber which, in turn, was maintained at constant temperature by automatic controllers.

The syrup was fed to the drying wheel by manual settings of a valve in the feed line. The viscous syrup would "set" if allowed to quiesce or if it aged too long and, as a result, there were always chunks of "set" resin in the feed which clogged valves. Not infrequently, the operator did not observe the plugged line before it had caked solid and sometimes it would cake so hard that the entire contents of the batch kettle would "set" and be lost.



Moreover, quality of product was not uniform because the operators could never maintain constant feed to the drying wheel. Before I instrumented the process, it was estimated that losses amounted to about 20 or 25 percent of production.

THE INSTRUMENTED PROCESS

Feed to the drying wheel was measured by watts power drawn by the motor. Two Weston high-speed thermal converters operated into a Leeds & Northrup high-speed pneumatic controller millivoltmeter. (It was the first installation of L&N's new air controller and it was the first time they had measured thermal converter voltages in process control.) This controller operated the feed valve to maintain constant load on the motor.

The viscous syrup required constant motion to avoid "setting." This was accomplished by pumping at a high rate and by-passing the unused portions back to the batch kettle. A pressure-difference controller measured back pressure on air purges across the main control valve and commanded the by-pass valve to maintain constant drop across the main valve.

If a "chunk" should not pass the main or by-pass valves, the action is as follows: Pressure drop across the main valve increases and the pressure difference controller opens its by-pass valve wide if necessary to by-pass all syrup and keep it in motion. Secondly, because of the plugged main valve, load on the spray wheel motor will decrease, thus opening the valve wide if necessary to let the chunk pass through. Load is then restored and the controllers readjust feed to normal. Both valves are butterfly.

When I last talked to the plant people about this installation (four years ago) I was told that it had returned its investment in a week's time. Since its installation, rejects have been nil and product quality is uniform.

# NEW DIAMOND-INDENTATION HARDNESS-TESTING METHOD SAVES TIME AND CUTS COSTS

By PAUL GRODZINSKI, Industrial Diamond Information Bureau, London, England

ONE OF THE most widely used methods for testing the quality of engineering materials ranging from the softest to the hardest is the indentation hardness test, and it can be considered as the standard non-destructive test following immediately after the tensile test. Whereas for the indentation testing of soft materials steel balls are used, for hard materials almost exclusively diamond points are used, owing to the recognized high hardness of diamond. In some instances, polished sintered carbides may be used, but their use is ruled out for materials of high hardness being increasingly used. The points of hardness testing diamonds are formed by several planes intersecting in a single point as in the Vickers and Knoop indenters, or by a conical or spherical point as in the Rockwell tester, Alpha durometer, etc. For a considerable time it has been recognised that an edge would constitute a more resistant form (U.S.A. Pat. 2,091,995 [Knoop] and Attinger). A diamond edge formed by two cones abutting on one another at their bases (Fig. 1) has hitherto been used only for cutting grooves for graticules and diffraction gratings and for scratch hardness testing (Talmage 1935), but not for indentation hardness testing.

A design has been developed in which the circular diamond edge can be swivelled about its center (Fig. 2), so that the complete periphery of the diamond can be utilized. Hence, when any part of the periphery becomes damaged, another undamaged part of the edge can be utilized. So far, in using a number of these diamonds over a considerable period of time (practically two years) in testing the hardest possible materials (sintered carbide, silicon carbide, sintered boron carbide, synthetic corundum, sintered alumina) not chipping of the extremely sharp edge (sharp at 600X magnification) has been observed.

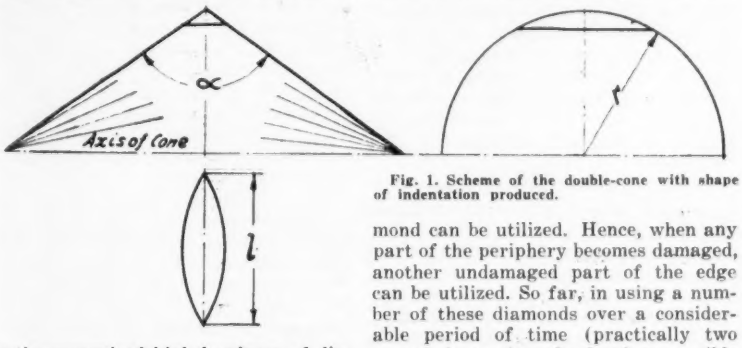



Fig. 1. Scheme of the double-cone with shape of indentation produced.

Comparing with the common experience in using diamond pyramids (Vickers) for the routine testing of sintered carbides and similar materials, whereby the sensitive point frequently breaks because of high stress concentration, this is much reduced in the case of an actual edge. If the diamond point of a hardness tester fractures, it has to be exchanged against a new one which has to be adjusted and check tests made. Very frequently, in the case of diamond pyramids, the readings obtained vary considerably; in our own experiments differences in hardness readings of up to 8 percent were found with different indenters. Now, with the new diamond indenter (Fig. 2) which can be mounted in sockets not larger than those for the Vickers machine and being provided with the same thread, no actual exchange is necessary, if the edge of the indenter shows nicks. The clamping attachment has only to be loosened, the diamond swivelled a fraction of a millimeter and clamped again. Of course, some rechecking seems to be necessary owing to the crystal structure of the diamond. Such a new diamond may have the life of twenty or more Vickers diamonds, even considering to repolish the latter.

The double-cone indenter can be fitted to all types of hardness testers and micro-hardness testers, but a higher limit of 2 kg. has been considered as useful. This allows, for instance, to mount the indenter to standard Vickers hardness testers, but the main field of application may lie in micro-hardness testing. Since with low ranges of load a great variation of "hardness" values is observed, as standard practice a load of 1 kg. was chosen, whereas lower loads are applied in certain instances such as thin specimens, thin coatings, etc.

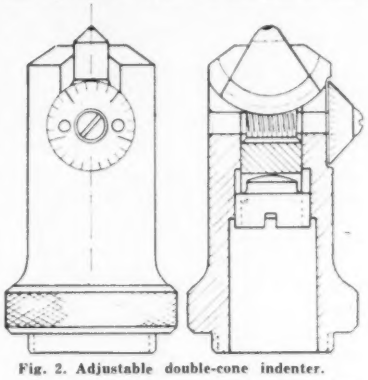


Fig. 2. Adjustable double-cone indenter.

Based on experiences with this indenter on a Bergsman micro-hardness tester, a new Macro-Micro hardness tester (Fig. 3) was developed (Brit. and U.S.A. Pat. applied) based on the following principles:

(a) Test pieces of arbitrary size and up to 5 in. height to be accommodated; impressions can be made up to 2 in. from the edge, and more, in particular cases; weights of specimens up to 20 lb. and more.

(b) Direct dead-weight loading during test, but avoiding any shock action.

(c) Mechanical loading system and optical viewing-and-measuring system intersecting at a suitable angle on the surface of the specimen to be tested.

(d) All sensitive operations to be made automatically in order to be independent of the operator. For instance, the loading time previously determined by the operator, is carried out electrically by a relay-operated motor.

After the test has been made, the indentation length is measured with a

microscope, the tube of which is arranged at 45 deg. to the test surface. This limits somewhat the use of high-power objectives, but a ⅔ objective can nevertheless, be accommodated without difficulty. This, together with a 12x eyepiece, gives a total magnification of about 150, which is sufficient in many instances. Higher magnifications can be obtained by reducing the size of the sample. The actual measurement is carried out with an eyepiece screw micrometer. The main principle is that indenter axis and microscope axis intersect at the precise spot on the surface of the sample to be tested.

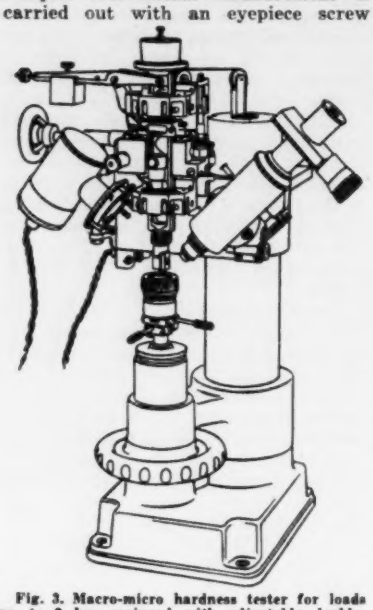


**Fig. 3. Macro-micro hardness tester for loads up to 2 kg. equipped with adjustable double-cone indenter.**

*Operation.* After the indenter and the optical system have been centered, the test load (weight) is placed on the platform, the microscope tube moved out of the way of the indenter path, and the indenter slide racked down by the left-hand wheel to a dead stop. The indenter point is then a few millimeters above the sample and the indenter stem held back by a hydraulic system. In this lowest position, the release lever for the hydraulic system is automatically tipped, opening the release valve and at the same time lighting a red signal lamp. When the hydraulic fluid passes, the two plungers supporting the indenter stem recede and allow the full load to be applied to the indenter stem, this being indicated by the red light going out. After a suitable period of, say, 15 to 30 seconds under full load, the indenter slide is racked back to the upper position, and this simultaneously generates hydraulic pressure for new tests. Now the optical system can be brought into focussing position and is withdrawn after measuring.

*Indenter.* Double-cone indenter (Brit. and U. S. A. Pat. Appl.) usually a double-conical diamond of 2 mm. radius and about 154 deg. included angle, with the same mount as the standard Vickers Diamond Indenter (3/16 Whitworth thread) adjustable through a range of plus-and-minus 30 deg. giving a large number of potential contact points. The tester can also be used with other hardness indenter points.

*Indenter Actuating System.* Steel (or aluminium) slide guided by two roller brackets, each comprising 6 adjustable rollers (ball races). The stem supports the platform on which weights up to 2 kg. can be applied, the weight of the stem being counterbalanced. The hydraulic system consists of two plungers supporting a bracket attached to the stem. The system is self-contained and is provided with both an automatic plunger pump and with an automatically operated release valve. The whole system is fixed to a slide which is removed from the field by a rack-and-pinion mechanism. The weight of the complete slide is counterbalanced when the microscope is in use. An electric lamp signal system is used for indicating the position of increasing load, this lamp being extinguished ultimately when the load position is reached.

*Optical System.* Baker microscope tube with rack-and-pinion movement mounted on a vertical turntable provided with worm drive adjustment. Beck intensity illumination unit, also adjustably mounted on the instrument head.

*Base.* 10 in. x 10 in. heavy cast-iron, indenter and optical system carried by heavy hollow column (3 in. external diameter). Specimen holder adjustable in height by handwheel-operated screw; 2 in. diameter; threads fully protected. For small specimens, clamping holder of 1 in. diameter fixed in screw mount, levelling of upper surface, fixed to cross-slide system (Unicam goniometer cross-slide). Small specimen holder exchangeable with platform of 2.5 in. or larger dia. for fixing large test pieces.

The hardness tester combined with the double-cone indenter seem to indicate a possibility of extending the range of micro-hardness testing out of the laboratory to the workshop, and to carry out investigations at the spot within a minimum time and no danger of breaking sensitive parts.

The assistance of F. A. Beard in constructing the tester and of W. Stern in useful suggestions and tests is gratefully acknowledged.

# PNEUMATIC BRIDGE SPEEDS PRECISION MEASUREMENTS

**By CARL G. HARD af SEGERSTAD, Chief Engineer, The Sandvik Steel Works Co., Ltd., Sandviken, Sweden**

WHAT can be done to cut production costs by use of the pneumatic bridge or "Delta" System? Many possibilities suggest themselves after one becomes acquainted with its fundamental principle, which is as simple as it is effective.

A constant-pressure air stream is divided into two parts, each one of which passes through a valve into a chamber of its own and from there through another valve out in the surrounding atmosphere. All four valves are mounted on a stem in such a way that when the whole set-up is in its normal, symmetric, central position, the air pressures prevailing in the chambers are equal. When the valve system moves out of its normal position, the increase in air pressure in one chamber equals the decrease in pressure in the other chamber. The bridge is made complete by adding a measuring instrument. This can be done by connecting each chamber to a bellows forming an integral part of a differential manometer, the pointer of which indicates the difference in pressure between the two chambers.

Quite a family of self-contained indicating and recording instruments based upon this principle has been in continuous use for several years. Among them are instruments for automatic control, automatic sorting, warning signalling, and the like. So far, the "Deltameter" Fig. 1, is the most popular one. Its outside appearance is shown in Fig. 2. This instrument, permitting linear magnifications up to a million and normally having two separate ranges of measurement, has adjustable electric contact equipment for make-and-break control. It can also be provided with various extra outfits such as connections for pneumatic remote indication or control or a "micropotentiometer" (voltage divider) directly mounted on the pointer axis in order to transduce the pressure-difference values into corresponding resistance values, etc.

Below are some examples of the range of applications of the "Deltameter":

*From differential manometer:* remote measurement in conjunction with other differential manometers; remote setting of certain regulating devices; cascade amplification for certain purposes.

*From "micropotentiometers"* (voltage divider) remote indication in conjunction with electrical instruments; remote setting and control in conjunction with electrical means.

*From electric tolerance contacts:* alarm signalling for warning, etc.; remote control—make-and-break; sorting.

*From pneumatic tolerance contacts:* same as above, but with pneumatic instead of electric transmission—in some circumstances cheaper and safer.

Furthermore, the main valve can be separated from the instrument and connected by means of a three-channel airhose. This is of value for measurement at places difficult of access or when several measurements are required on a small workpiece, for regulation processes or in conjunction with separate appliances for measurement of forces, torques, etc. Fig. 3 shows an application for control of rolling pressure, Fig. 4 shows how a potential-divider type of transmitter is mounted, and Fig. 5 shows an automatic sorting machine. (Ed. Note: No space for these other three photographs.)

This instrument was originally developed for production control of high-quality Swedish strip steel with thickness tolerances not exceeding 0.003 mm. When the rolling speed exceeds a certain limit, manual control is inadvisable, and production should be based upon instrumental measurement and automatic control. This applies also to the adjustment of the roll neck pressure in order to correct variations in the thickness of the strip.

Here are some examples of how instrumentation and automatic control will help cut costs:

*Human:* Less experienced workers may replace their foregoers who, in turn, can be transferred to more skill-requiring work. Under certain conditions, one worker may be available to run more than one mill with corresponding saving of man-hours. Less human

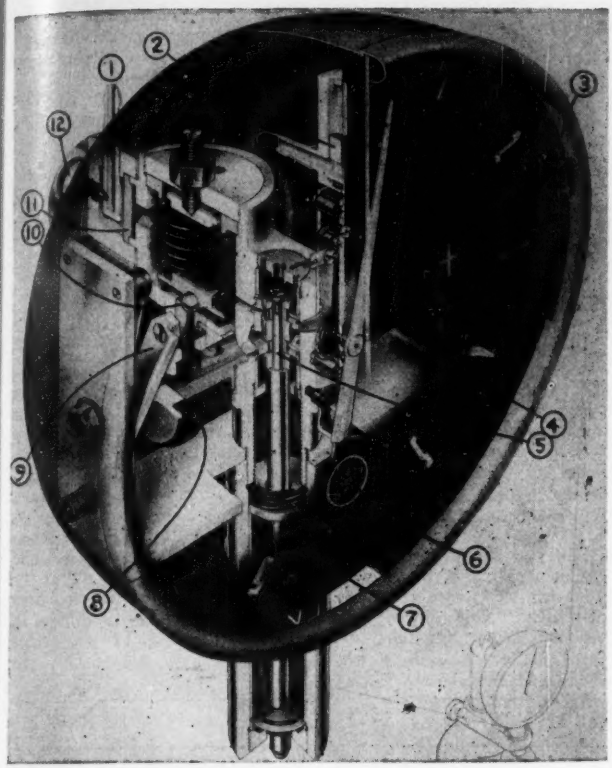



Fig. 1. "X-ray" of the "Deltameter." (1) Air inlet. (2) "Sufficient working pressure" indicator. (3) Adjustable limit indicator. (4) Movable electric contact. (5) Main ("Delta") valve. (6) Measuring-range index giving the value of one dial-scale division. (7) Level for range setting. (8) Bellows forming part of differential manometer. (9) Yoke of differential manometer. (10) Constant-pressure bleeder valve. (11) Filter. (12) Adjustable reducing valve.

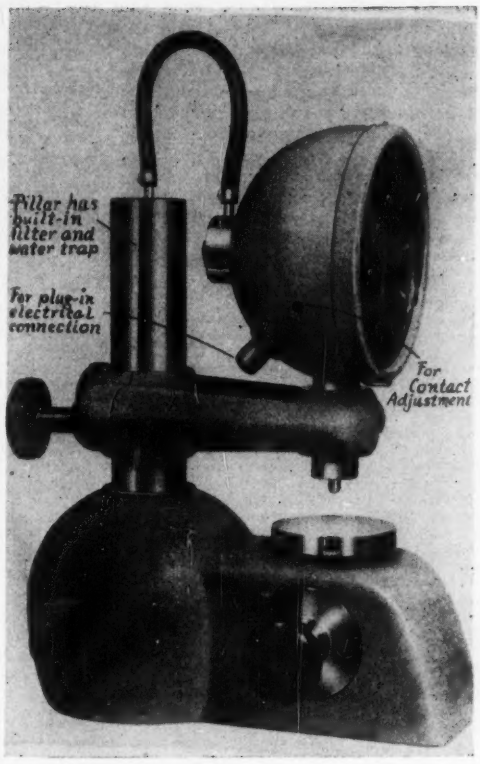



Fig. 2. "Deltameter" mounted on stand.

fatigue will result despite higher rolling speeds.

*Machine*: The rolling mill can be made much better use of, for its speed can be increased a good deal, with consequent savings in time and money. Machine defects can be more easily detected for they will show up as periodic errors indicated by the instrument dial. This means saving labor, machine parts, and products.

*Product*: The production capacity can be increased, sometimes more than 100 percent, and the product itself will be more even and can be kept within closer tolerances. The scrap tonnage would thus decrease, saving raw materials and cutting down transportation of scrap back to the furnaces.

*Customers*: The customers would get a far more uniform product at prices which might not exceed their former level, a fact which also would contribute to better relations between supplier and customer.

It should be obvious to anyone familiar with instruments that any physical magnitude which is convertible to units of length can also be measured, indicated and controlled by devices based upon this pneumatic bridge system. Thus, by reason of its simplicity and dependability, it may be used for solving many measuring and control problems in today's industry. It should be borne in mind that very few, if any, production lines are run at speeds calling for the velocity of light in connection with automatic control. In most instances, sound velocities in air together with servomechanisms of relatively small inertia are speedy enough to meet industrial needs. In the case of such applications where the "Delta" system can be conveniently used, the user is likely to obtain satisfactory results both in regard to production and in regard to economy.

*Technical data for the "Deltameter"*:
Air supply pressure: at least 14 psi.
Air consumption: about 10 cubic feet of free air per min.
Measurement ranges: 10 and 20 microns or 100 and 200 microns.
Accuracy: about 2 percent of total scale value.
Total instrument weight: 4 lbs.
Weight of separate main valve: 4 oz.

# AUTOMATIC OPTICAL CONTOUR FOLLOWER

By T. M. BERRY, General Engineering and Consulting Laboratory, General Electric Co., Schnectady, N. Y.

EXCESSIVE time and associated high cost of the usual methods of producing master patterns of airfoil shapes have led to the development of an Automatic Optical Contour Follower which cuts the cost of producing master patterns to a small fraction of its former figure.

Most of the drafting is eliminated and a large reduction in shop cost is accomplished by the use of this automatic machine tool controller—actually a gaging instrument which automatically adjusts and controls a machine tool to accurately cut a machined part directly from an undimensioned line drawing.

The Automatic Contour Follower was developed in the General Engineering and Consulting Laboratory of the General Electric Company for use by The Pratt & Whitney Div., United Aircraft Corp., East Hartford, Conn.

Developmental work in turbines requires the building of numerous developmental turbines and turbine wheels, all different. The cost of labor and the time required between the inception of a new design in the engineer's mind and the production of the master pattern are both excessive. The actual direct cost runs into thousands of dollars for each master. The indirect cost may be much greater. Several months

usually elapse between the time the design of a blade is started and the completion of the master. A new design may be obsolete before it can be produced. A new design may not even be required because of previous design changes which have taken too long to evaluate.

The usual procedure when the design engineer decides on a new shape for a turbine blade is as follows.

*Step* 1. The engineer's ideas are given to a draftsman who draws (usually on a coated glass for dimensional stability) the shapes to be produced, usually working in a much enlarged size for accuracy.

*Step* 2. After the shape is drawn accurately to scale, the drawing is dimentioned by locating enough points around the curve to allow a template to be machined to the required accuracy at the located points. The distances of these points are accurately measured from two coordinate axes, multiplied by the scale factor and placed on the drawing.

*Step* 3. Before a template can be machined from the drawing, someone must decide on the size of the cutting tool to be used in machining the template and produce another set of dimensions which are points on the traverse of the center of the cutting tool to cut the desired shape. The dimensions of points on the traverse of the cutting tool may be placed on the drawing. This not only requires a different drawing for each size and shape but one for each cutting tool diameter and may involve endless complications and difficulty in taking care of wear on the cutting tool, machining characteristics of the material to be cut, etc.

*Step* 4. A template is machined point by point so that it is accurate at these points. It is then faired in with hand tools to form a smooth curve between points.

*Step* 5. After a number of templates have been produced, representing several sections along the length of a master blade (usually between 5 and 20) corresponding sections of the master are machined. For this a template follower is used, again fairing by hand between machined sections on the master blade.

The automatic optical contour follower when applied to producing master turbine blades completely eliminates steps 2, 3, and 4.

After a drawing is made on glass it is photographically reproduced on a steel plate. It appears on the steel plate as a black line on a white background. The steel plate with the drawing on it is placed in position in the optical contour follower.

The optical scanner of the follower picks up the line and adjusts itself to center on the line.

The scanner is carried on a rotatable arm at an adjustable distance from the center of rotation. The length of arm corresponds to the radius of the cutting tool.

When the scanner picks up the line it not only centers itself on the line but the scanning arm rotates until it is normal to the line at the point of scanning.

By means of a hand-adjusted speed control, the scanner moves along the line, automatically keeping centered on it and keeping the scanning arm normal to the line at all times. The traversing speed can be adjusted up to 6 inches per minute. Thus the center of rotation of the scanning arm is moved around the curve at a constant distance away from it and at constant speed. This is accomplished by means of traverse and longitudinal lead screws which move the scanning head with respect to the drawing in the desired manner.

The optical scanner of the contour follower "looks" at a small segment of the line to be followed. The image of this segment is rotated at 3600 rpm. by means of a synchronous motor. When the image of the line passes an off-center aperture at high speed, voltage pulses are produced in a phototube amplifier which control thyratron-operated d-c. motors to drive lead screws of the follower to keep the scanner on the line and the scanning arm normal to it.

The lead screws of the contour follower are coupled to the corresponding lead screws of a machine tool by power selsyns working through gear reducers. A cutting tool whose radius corresponds to the radius of the scanning arm moves with respect to the work piece to reproduce the section of the master blade represented by the drawing.

The required number of sections are cut directly on the master blade. The master is faired by hand tools between sections and the job is completed.

The fact that the length of the scanning arm is adjustable makes it possible to cut the same shape in different sizes from the same drawing. This makes it possible to use different size cutting tools to cut the same shape from the same drawing. It makes it possible to adjust to take care of tool wear and makes it possible to take a rough cut and then a finish cut removing a very small uniform amount of material all the way around the contour with the finish cut.

Since the same shapes can be cut from the same drawing in different sizes and since any size cutting tool may be used to cut the same shape from the same drawing, the cost of step one of the usual procedure is very greatly reduced.

*Over-all.*—The actual cost of producing a metal master pattern has been reduced about 75 percent and the production time reduced by about 80 percent with accompanying indirect saving.

# MICARTA ORIFICE PLATES

**By V. A. RIGGIO, 20 Green Acres, St. Louis, Mo.**

IN applications requiring the measurement of corrosive liquids, erosion and corrosion enlarged our orifice plates. This introduced errors prohibited by our demand of close control. After making orifice plates of nickel, Monel, Hastelloy B, and all types of stainless steel, I tried making one of half-inch thick Micarta sheet stock. This very fine grade of Micarta lends itself to close machining tolerances such as plus-or-minus 0.0005 inch, which normally is satisfactory for the I.D. of orifice plates.

The only limitation we have found for using Micarta orifice plates was 100-degree temperature. Pressures up to 200 psig haven't broken or even distorted any of these plates.

I've had six such orifice plates in a line measuring a liquid with free hydrochloric acid in it for more than eight months and upon inspection found them perfect.

The downstream side must be bored to the orifice edge from the pipe I.D. to reduce the thickness of the orifice edge.

## INSTRUMENT EDUCATION NEWS

### Instrumentation Course at L. A. H. J. C.

WILMINGTON, Calif.—A course in Instrumentation is being given at the Los Angeles Harbor Junior College (a technical institute under the Los Angeles Junior College District):

1. Instrumentation and Control

Indicating, recording and controlling instruments. Static and dynamic behavior of the operative components used in measuring instruments. Construction of typical instrument parts; specifications; compensation; bearing friction, assembly, calibration, and inspection. Fundamental instruments; limits of error.

2. Mechanical Instruments

Mechanically activated instruments for indicating, recording, and controlling mechanical parts and fittings; coils, springs, pointers and dials; balancing and leveling; jewels and diaphragms, chasses and cases. Behavior and properties of metals; processing and heat treatment; joining and corrosion resistance.

3. Electrical Instruments

Repair, maintenance, calibration, adjusting, and testing of precision electrical measurements at d.c. and low frequencies; measuring impedance, voltage, current, frequency. Principles and apparatus involved in the production, measurement, transmission, and reproduction of sound by electrical means.

4. Electronic Control and Measurement

Electronic devices for control and measurement; phototube devices, voltage regulators, water-level controls, spot-welder controls, sensitive wattmeters, voltmeters, ohmmeters, high-speed recording instruments, stroboscopes.

5. Scientific Instruments

Design, construction, and repair of instruments used in surveying, navigation, aviation, medicine, meteorology, optics.

Petroleum 5. Process Flows and Instruments.

A study of flows, in typical refineries, from crude oil to finished products; blueprints of flows of typical units; functions and locations of auxiliary equipment; types and uses of refinery instruments.

### Instrumentation Course at Bucknell U.

LEWISBURG, Penna.—A course in Industrial Instrumentation was begun February 9, 1950, for senior and graduate chemical engineering students. Given by Assistant Professor Morton Smutz, it consists of two periods per week and will run through May, with a total of thirty-one periods, as follows:

Period No. 1—General announcements. Survey of the course. *Standards.*

2—*Pressure and Vacuum Gages.* Liquid-Column Pressure Gage, Manometer Theory, Barometer, Recording Liquid Column Gage, Bell-Type Pressure Gage, Limp Diaphragm Gages, Piston Gage.

3—Bourdon Pressure Gage, Metallic-Diaphragm Gage, Metallic Bellows Gage, Pressure Measurement by Change in Physical Property of Measuring Element.

4—*Indicating and Recording Thermometers.* Fundamental Working Parts, Thermometer Bulb, Capillary Tubing, Actuating Mechanism, Recording Mechanisms. Class I Bulb Thermometers.

5—Class I Bulb Thermometers continued. Class II Vapor Pressure Thermometers.

6—Class III Liquid Filled Thermometers. Indicating and Recording Thermometer Installation Problems. Maintenance and Testing.

7—*High Temperature Pyrometry.* Thermocouples. Theory, Metals Used, Accuracy, Standardizing, Protection Tubes, Speed of Response, Compensating Leads.

8—Thermocouple Wiring Arrangements, Proper Installation, Millivoltmeter, Cold Junction Compensation, Care and Maintenance.

9—Potentiometer, Cold Junction Compensation. Galvanometer Design, Indicating and Recording Potentiometric Pyrometers.

10—Accuracy of Recording Potentiometers, Maintenance and Testing. Resistance Ther-

*Continued on page* 394

# ELECTRICAL PICKOFFS *for* Instrumentation *of* PILOTLESS AIRCRAFT

By JACK ANDRESEN, Kollsman Instrument Division of Square D Company.

THE advent of pilotless aircraft for military purposes has necessitated the development of a group of special instruments whose function is to provide either a signal for the control of the aircraft, or a signal for use in a telemetering system which radios the information to observers on the ground.

It is the responsibility of the engineer in charge of control and telemetering for a particular pilotless aircraft project to select the most appropriate devices. His choice is influenced by a great number of factors, some over which he has control and others which are a result of the original specification such as:

(1) Size of aircraft
(2) Performance of aircraft
(3) Primary and secondary power sources
(4) System of telemetering (pulse time, frequency modulated signal on an FM carrier, phase comparison system, etc.)

It is the purpose of this paper to aid the engineer in this choice.

The instruments consist basically of two parts: a sensing mechanism and an electrical pickoff which changes the mechanical indication to an electrical signal.

The sensing mechanisms are such instruments as accelerometers, gyros, pressure gages, or thermometers, with special characteristics in regard to size, weight, useful life, temperature compensation, and *G* load compensation as required for the particular type of pilotless aircraft.

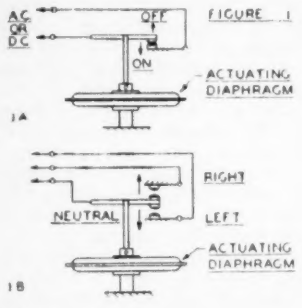


FIGURE 1

Electrical pickoffs for these mechanisms are available in a number of diverse forms, each of which will be described and analyzed briefly.

## Contact Pickoffs

Contact pickoffs give the simplest form of electrical signal. As shown in **Fig. 1**, they may be used with a.c. or d.c., and may be in the form of a simple on-off switch, a left-right switch with neutral or "dead" zone, or a multiple-contact switch. The switch is usually directly operated by the sensitive element and results in a circuit being either opened or closed at a selected value of the function being measured. For measurements where this elementary signal is sufficient, the contact offers a cheap and simple solution. However, an important factor in contact work is often overlooked. To make a reliable contact, even when vacuum-tube amplification is used, a measurable contact pressure must be established. This requires that a certain increment of signal will of necessity exist between the "on" and "off" positions. This difference is increased by adhesion between contacts, which appears always to be present, by dirt, and by any welding which might occur as contact is closed. In general, the higher the pressure between contacts, the more reliable the device. The large increment in signal required to produce high contact pressure is detrimental to high accuracy for telemetering pickups; and, when the switch is used in a servo control system, it has a strong tendency to cause hunting or instability.

Miniature snap switches offer the advantage of having the contact pressure after the snap definitely established, hence its point of contact is unaffected by small amounts of dirt. However, the contacts, just before the snap in either direction, suffer from having the contact pressure gradually diminish to zero. Vibration at this point may cause intermittent contact, arcing, and premature snapping of the switch, with resultant loss of accuracy of the device.

Using a "dead" zone s-p.d-t. switch arrangement in a servo application will sometimes cure the stability trouble caused by a simple on-off switch, but the ultimate accuracy can be no greater than the width of the "dead" zone. Multiple contacts are sometimes employed on either side of the center position, giving additional signals which may be used to anticipate the approach to null. This arrangement is used for securing stability where the s-p.d-t. switch with very small "dead" zone is not sufficient.

TABLE I

| TYPE PICKOFF | ADAPTABILITY TO DC | ADAPTABILITY TO AC | SIGNAL POWER REQ'D | OUTPUT POWER | RELATIVE SIZE & WGT | RESOLUTION | RELIABILITY | ACCURACY | RUGGEDNESS | APPROX. COST |
|---|---|---|---|---|---|---|---|---|---|---|
| CONTACT | X | X | H | L | L | P | P | F | P | L |
| STRAIN GAGE | P | E | H | L | L | H | F | P | F | L |
| VARIABLE RELUCTANCE | - | X | ML | M | M | H | E | P | F | L |
| POTENTIOMETER | X | X | H | H | ML | M | F | F | F | M |
| "E" PICKOFF | - | X | ML | M | M | H | E | E | E | H |
| SYNCHRO | - | X | L | M | M | H | E | E | E | H |
| CAPACITIVE | - | X | L | L | H | H | P | P | F | M |
| THERMOELECTRIC | X | X | L | H | L | H | P | F | F | M |
| PHOTOELECTRIC | X | X | L | L | H | H | F | F | F | M |

E - EXCELLENT
F - FAIR
P - POOR
H - HIGH
M - MEDIUM
L - LOW
X - APPLICABLE
- - NOT APPLICABLE

## Strain Gages

Strain gages (Fig. 2) are unique in having no sliding or contacting parts. The signal is attained by the increase or decrease in resistance of a wire as it is thinned out by stretching or contracting.

The resistance of a piece of wire is proportional to its length divided by its area. Since the product of length and area of a particular piece of wire remains nearly constant, the resistance change of the wire under strain is roughly proportional to the square of the elongation.

Strain gages may be divided into two classes: the free-wire type where the wires are suspended in a gas or vacuum between two relatively movable mechanical members, and surface strain gages where the wires are bonded by suitable cement to a surface of a member subjected to strain. The latter type are commonly used in missile applications where the surface is a structural part of the craft, a pressure-sensing diaphragm, or small beam bent by any sensing element.

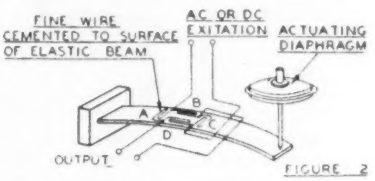


FIGURE 2

Most instrument parts and structural members are working well within the elastic limit, so that the strain gage experiences extremely small elongation. For this reason the resistance change, in spite of the square law relation is only a few percent. In order that the wire may be exposed to an elongation similar to that of the surface whose elongation is to be measured, it must be secured to the surface at all points along its length and yet must be electrically insulated from it. Most cements used to bond the wire to the surface are of semiplastic nature so they will not crack under strain. As a result of this and other factors, strain gages are subject to change in

*Presented at the 1949 Semi-annual Meeting of the American Society of Mechanical Engineers.

calibration or drift with age. Wheatstone bridge type strain gages, in which all of the legs are attached to the surface being elongated, can have very small temperature error if the elements are uniformly bonded to the surface. Uneven thickness of bonding material can cause temperature differences between the various wires which result in errors. Theoretically strain gages can be used in a-c. or d-c. circuits, but their low voltage output favors a.c. where amplification is more easily accomplished. Although much progress is being made to minimize drift, or change of accuracy with age, strain gages are usually calibrated before each flight where quantitative data is required.

Advantages of the strain gage are its small size and weight, negligible phase shift in an a-c. system, instantaneous response, proportional output signal, high resolution and reliability. Disadvantages include tendency to change calibration (drift) and the small output voltage signal. A considerable force is required to produce strain on the surface, hence the strain gage is not readily adaptable to free gyros, magnetic compasses, etc., where even small forces are not tolerable. They can be effectively used in the measurement of structural strains, in high-response accelerometers, vibration pickups, and certain types of pressure gages.

### Variable-Reluctance Pickoffs

Variable-reluctance pickoffs (Fig. 3) are usable only with a.c., but have the advantages of small size, high resolution and simplicity, and adaptability to FM telemetering schemes. They are subject to calibration drift due to change in resistance of winding and, to a lesser degree, by change of permeability of the core with temperature. Compensation for temperature error is attainable by thermistors or by selection of suitable low-coefficient wire and core materials. For telemetering, variable-reluctance pickups are used as elements of oscillator circuits and their output is converted into a frequency. Special care must be exercized to minimize temperature effects on other elements of the oscillator circuit.

Variable-reluctance devices are sometimes used in a self-balancing inductance bridge arrangement with a second variable reluctance pickoff which is driven by a servo motor. Here temperature effects cancel, if both units experience the same temperature change.

### Variable-Resistance Pickoffs

Variable-resistance (so-called "potentiometer") pickoffs (Fig. 4) are the most widely used type. Operating satisfactorily on either a.c. or d.c., they have the advantages of a powerful output signal, no phase shift, moderate weight and cost, and adaptability to a wide variety of instruments. They can be used as d-c. voltage dividers for pulse-time telemetering; in a resistance-capacitance network they will give a phase shift signal. Connected as an a-c. voltage divider in a self-balancing bridge the variable-resistance pickoff becomes part of a null-seeking type of servo system. Two or more of these units may be used as variable resistances in a self-balancing

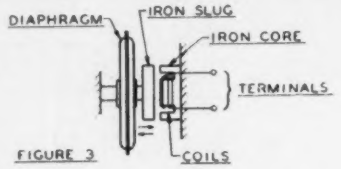


FIGURE 3

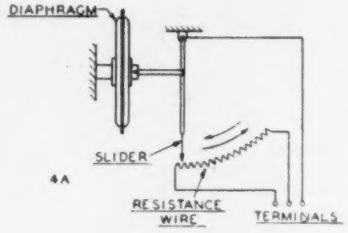


FIGURE 4

bridge circuit so that their sum, difference, product, quotient, reciprocal, etc., may be obtained.

The resistors commonly used on instruments for pilotless aircraft can control up to a watt of power for full range. Resolution is limited by the number of turns of resistance wire and by the friction of instrument and sliding contact. The smallest low-temperature-coefficient resistance wire used for pickoffs commercially available is one one-thousandth of an inch in diameter including insulation. With the resistor hermetically sealed in an inert atmosphere, these pickoffs can be operated reliably after a year on the shelf. With this construction contact pressure as low as one gram can be relied upon.

Disadvantages of the resistor pickup are its limited resolution of winding, friction load on sensing element, finite life due to wear, and susceptibility to corrosion unless hermetically sealed. Despite these drawbacks, the advantage of large output signal with d-c. operation make the resistance pickoff the most popular for guided-missile work where only d.c. is available and where size, weight, and simplicity outweigh other considerations.

### Inductive or "E" Type Pickoffs

The inductive or "E" type pickoff is an a-c. device shown in Fig. 5A which can be used as a left-right senser with error proportional to output, or as part of a follow-up servo system. The rotor is moved by the sensing instrument, while the stator containing electrical windings is either stationary or is mounted so as to be driven by a servomotor in response to rotor movement.

Referring to Fig. 5A: the input coils surrounding laminated iron pole pieces A and B are connected to an a-c. source in series bucking, so that

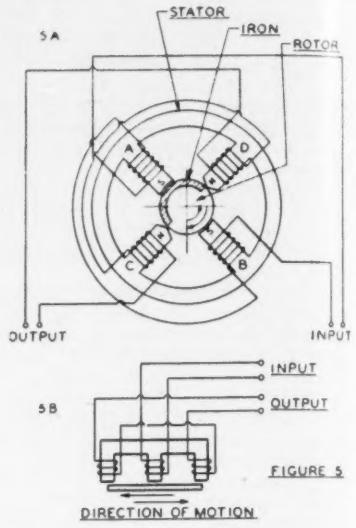


FIGURE 5

A and B have the same magnetic polarity. Coils around poles C and D are connected in series-aiding across a diameter so that, with the semi-cylindrical iron section of the rotor in symmetrical position as shown, the flux will be equal but in opposite directions in coils C and D and, therefore, will result in zero output. If rotor is moved slightly clockwise, flux in D will predominate and a signal of one polarity (say in phase with source) will result. A slight rotation counterclockwise will cause flux in C to predominate and a signal out of phase with line will result. With rotor in a position 180 degrees from that shown, a clockwise rotation will cause more flux through C, rather than D. Thus, although two null points are present the off-null signals are reversed and no ambiguity of output signal exists for signals off the null.

The relationship between output voltage and angular displacement from the null position may be varied within wide limits by shaping the rotor and stator pole pieces. Generally, it is desired to have as steep a linear voltage gradient as possible for small angular deflections with the gradient decreasing rapidly above about five degrees. The narrow pickup pole pieces shown in Fig. 5A tend to accomplish such a voltage-displacement relationship. In this construction there is a weak torque reaction on the rotor when the stator input windings are energized, which tends to pull the rotor within a few degrees of the symmetrical or null position. Then a reversal of torque occurs so that the rotor must be pushed to the null. As the exact null is approached still closer, reaction torque falls smoothly again to zero.

"E" pickoffs are used on gyro gimbals, altitude and airspeed holding controls for autopilots, and to follow

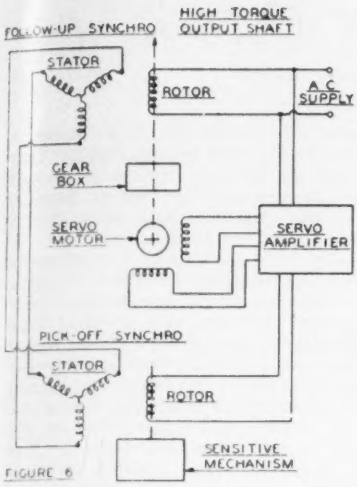


FIGURE 6

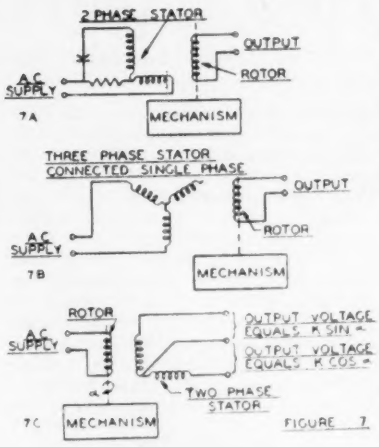


FIGURE 7

up weak shaft rotations for torque amplification. They are relatively more expensive and complicated than above-mentioned pickoffs, but may be designed to be statically balanced, hence free from acceleration errors. Choice of wire size in windings permits latitude in selection of voltage level for input and output.

Fig. 5B shows another arrangement of this pickoff adaptable to sensing straight-line rather than rotary motion.

## Synchros

Synchros offer the most sophisticated pickoff for a-c. servo systems as well as certain types of telemetering. The physical construction of a conventional synchro is similar to that of a three-phase wound-rotor induction motor. The laminated stator core usually has nine or twelve pole pieces on which are wound a two-pole three-phase coil set. The laminated rotor core has two or more pole pieces and a single-phase winding which is terminated in a pair of slip rings. Systems employing synchros differ from those using "E" pickoffs in that with synchros the servomotor need not be mechanically linked to the sensing instrument for follow-up. Instead the sensing element synchro electrically reproduces its angular position in a second remotely-located synchro, eliminating the need for mechanical connections. This makes them particularly adaptable to autopilot and remote-control systems where the signal is obtained at one location and the elevators, throttles, cowl flaps, etc., to be controlled are at a distance.

Fig. 6 represents schematically the use of a pair of synchros in a typical remote control servo system. The follow-up synchro has its rotor energized from an a-c. source. This creates in the rotor core a flux which links the stator core inducing three a-c. voltages in the three Y-connected stator windings. These voltages are all in phase with each other but vary in magnitude depending upon the position of the rotor. The three stator leads are connected to similar leads on the pickoff synchro, whence currents flow in accordance with the stator voltages in the first mentioned synchro. These currents produce a resultant radial flux in the stator core of the pickoff synchro whose angular position changes degree for degree with the rotor of the follow-up synchro. When the rotor of the pickoff synchro is at right angles to its stator flux, no flux will link its coil and no voltage will appear across its leads. This condition is described as a null position of the system. If, however, the rotor is other than at right angles to the flux, a voltage is induced in its winding which is amplified and causes the servo motor to run either forward or reverse, depending upon which side of the null the rotor is positioned. The servomotor is geared to the follow-up synchro and rotates its rotor in such a direction that the voltage in the pickoff synchro rotor is brought to null.

Synchros can also serve as phase shifters (Fig. 7A) as inductive pickoffs (Fig. 7B) or as sine-cosine generators (Fig. 7C). In addition to the conventional synchros which have a wound rotor and slip rings, there are available special synchros designed to be positioned by sensitive instruments. They have very light rotors, no brushes and small electrical reaction. With these, excellent resolution and accuracy, moderate power output, and ruggedness can be expected.

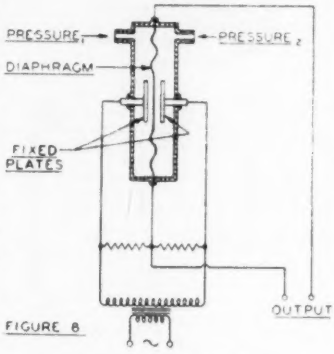


FIGURE 8

## Capacitance Pickoffs

The "Capacity Pickoff" has been used both in an a-c. capacitor bridge system as shown in Fig. 8, and as an element of an oscillator for FM telemetering. It is essentially friction- and reaction-free and has excellent resolution. However, its very high impedance output makes it subject to error owing to resistance leakage and electrical pickup in the leads.

## Photoelectric and Thermoelectric Pickoffs

Photoelectric and Thermoelectric pickoffs are used where no reaction load on the instrument is tolerable. The varieties of photoelectric pickoffs are too well-known to deserve description here. Often they are used in on-off circuits in the same manner as contact pickoffs. Where the light source and amplification are rigidly controlled. a proportional signal may be obtained by having the sensing element cause the photocell to be progressively obscured from the light. Photoelectric pickoffs of this type give high resolution, no friction or reaction, immediate response, and good accuracy. Usually, however, photoelectric arrangements require excessive space and relatively elaborate amplifying equipment to raise the weak photocell signal to usable power levels.

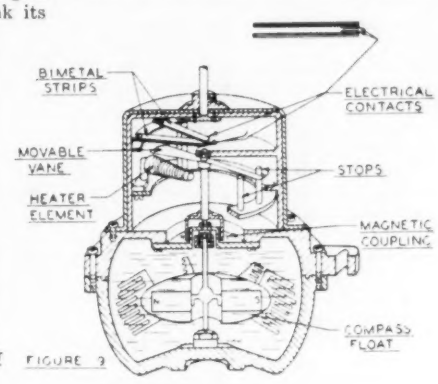


FIGURE 9

In the thermoelectric scheme shown on magnetic compass in Fig. 9 the contacts on the bimetal strips bend either toward or away from each other in accordance with the position of the shadow of the interrupting vane either making or breaking the contacts. Ambient temperature changes bend both bimetals equally and do not affect relative position of contacts. As expected, time lag in this system is great. A response of 0.2 second is about the best that can be reliably obtained by the thermal pickoffs, but the other advantages of an on-off photoelectric system remain with no electronic amplification required.

To summarize the various characteristics of the pickoffs described above Table I has been included. Comparisons in this table are necessarily qualitative and subject to revision as the art develops.

# Multiple Pressure-transfer Device

By RICHARD S. DAVEY, Langley Aeronautical Laboratory, NACA

A DEVICE for transferring simultaneously up to thirty pressures from a rotating object to a stationary manometer has been developed at the 16-foot high-speed wind tunnel of the National Advisory Committee for Aeronautics at Langley Air Force Base, Virginia. The device operates satisfactorily at speeds up to 6000 rpm. The design employed can be utilized to provide a device which will transfer many more than thirty pressures simultaneously. The device is being utilized to measure pressures on propellers, compressor blades, and rotating airfoils operating at transonic airspeeds.

The development of the synthe-seal transfer device was started in March 1948 and involves the use of Marlin-Rockwell Corp. "Synthe-seal" ball bearings which are available in various sizes. Each bearing has a soft synthetic rubber seal on each side, providing a double seal between each pressure transfer chamber. The rotating seal is formed by a pliable synthetic rubber wiping lip in contact with a ground concentric sealing surface on the inner race of the bearing as illustrated in Fig. 1. Also shown in Fig. 1 is the static seal at the outer race. The seals on each side of the bearing snap into a retaining groove in the outer race and thus are readily removable.

The 30-cell device is shown in Fig. 2. Hollow shaft A is utilized with pressure tubes B soldered in place. The pressures on the rotating object are transmitted through the rotating tubes B to the airtight transfer chambers each of which is formed by one rotating spacer C, four "O" ring gaskets D, two "Synthe-seal" ball bearings E, and one stationary spacer F. The pressures in the transfer chambers are transmitted to a manometer through the tubes in the stator spacers. A water jacket carries away the heat generated by the bearings, thus prolonging the life of the synthetic rubber wiping lip.

When a positive pressure is applied within the transfer chamber formed by two "Synthe-seal" bearings, the two inner seals, one on each bearing, are effective. When a negative pressure is applied, the two outer bearing seals will prevent leakage. The bearing seals are slightly preloaded, making it possible to measure nearly equal pressures in transfer chambers adjacent to one another. During the development of this unit, it was learned that the bearing seals would be more satisfactory if the preload was increased by installing the seals reversed: with the steel backing toward the outside.

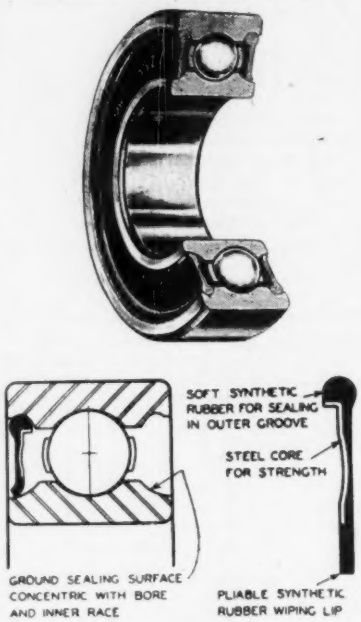

SOFT SYNTHETIC RUBBER FOR SEALING IN OUTER GROOVE
STEEL CORE FOR STRENGTH
GROUND SEALING SURFACE CONCENTRIC WITH BORE AND INNER RACE
PLIABLE SYNTHETIC RUBBER WIPING LIP

Fig. 1. Detail of synthe-seal ball bearing.

No leaks developed in transmitting pressures ranging from 0 to 20 inches of mercury during 200 hours of intermittent operation at a speed of about 2200 rpm. After this operation the bearing seals were inspected and found to be in excellent condition. Accordingly, it is estimated that the device will operate for about 500 hours at this speed with little maintenance. With operation at speeds of 3000 to 4500 rpm, however, replacement of some seals must be made after about 75 hours' operation. At speeds of 6100 rpm, no leaks occurred during ten hours of operation.

Speeds higher than 6100 rpm. may be possible with a device of this type, particularly if smaller bearings are used and if coolant is applied inside the hollow shaft through one of the transfer chambers. The bearings run appreciably cooler if the grease in the new bearings is removed and replaced with several drops of light high-grade oil.

Some features of the "Synthe-seal" device are as follows:

1. The device is easily constructed of materials readily obtainable.
2. It is dependable and requires little maintenance.
3. It does not require rotation for leak checking.
4. Maintenance is simple and inexpensive.
5. The maximum pressure difference transferred is virtually independent of rotational speed.
6. Very little power is required for operation.

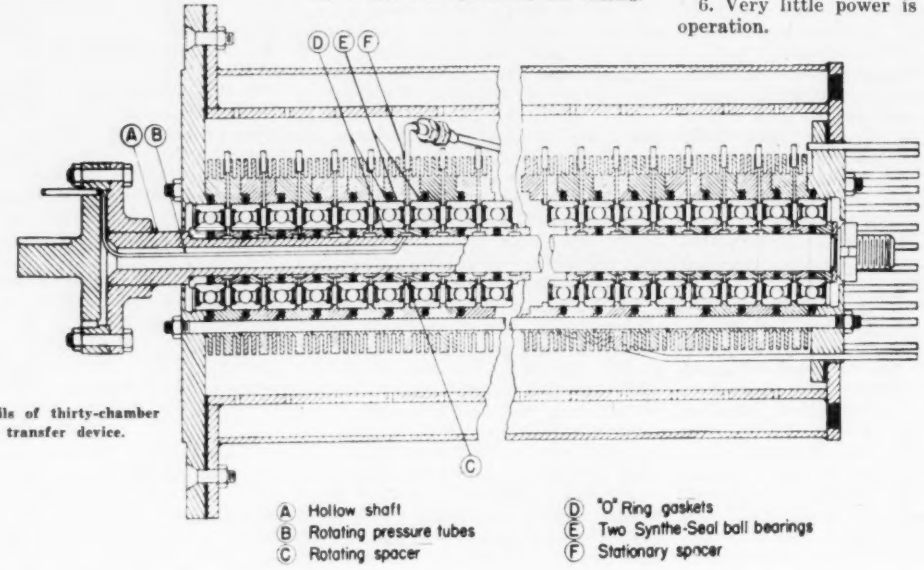



Fig. 2. Details of thirty-chamber pressure transfer device.

# A MAINSPRING DYNAMOMETER

By J. E. HENDRICKS, Supervisor of Watch Research Laboratory, Hamilton Watch Co., Lancaster, Pa.

## INTRODUCTION

THE continual search for fundamental information on watch mainsprings, which results in their improvement, would be seriously handicapped were it not for the development of adequate testing procedures. To better understand the difficulties encountered in developing test equipment for use in mainspring research, a background of the various characteristics of watch mainsprings is desirable. These characteristics may be conveniently divided into three main groups: those determining a smooth even flow of power; those affecting the loss of torque due to fatigue, or "setting"; and those which determine the corrosive, or breakage tendency. It was the study of the first of these groups which necessitated the development of the Dynamometer.

Referring to Fig. 1, where a Hamilton 16 size (railroad model) mainspring is shown in its free-sprung condition, it is observed that the general shape is that of a reverse bend. Fig. 2 shows the same mainspring wound into the barrel but left essentially unstressed. Fig. 3 shows the mainspring in the barrel fully stressed as it would appear after the watch was fully wound. Fig. 4 shows a magnified cross-section of a typical mainspring. By comparing Figs. 2 and 3 it is seen that the unwinding action of a mainspring consists of uncoiling from around the arbor to coiling around the inside of the barrel. This uncoiling action involves not only a radial movement of the coils but also relative motion between them, for the radius of the various coils is constantly changing, causing each one to slide along its neighbor.

Observation of this uncoiling action reveals several features which are also evidenced both in the motion of the balance wheel in a watch and in the type of torque curve obtained from most mainspring torque measurements. The first of these is a result of static friction, which necessitates a greater force to start the coils sliding than is necessary to keep them in motion. This condition is noticed in the unwinding action by the unevenness of motion of the coils. Instead of moving every ⅛ of a second, which is the time of each beat or half-oscillation of the balance wheel, they appear to remain stationary for a period of several seconds and then move a relatively large amount. The beginning of this motion is rather fast, starting suddenly, but its ending is rather gradual. Apparently moving in this fashion, the spring builds up greater potential energy than is indicated by the position of wind and it is not until this built up energy is dissipated that further unwinding action takes place. Naturally, this type of motion causes a variation in torque delivery resulting in an uneven flow of power through the gear train, thereby affecting the strength of the impulse applied to the balance wheel. Inasmuch as this action is irregular, it is difficult to repeat the same pattern of delivery of torque on different unwinds.

Another effect of this force of friction, readily seen on torque curves of mainsprings, is that, when winding, this force is added to the torque required to wind the coils, but when unwinding it is subtracted from the torque delivered by the spring. This frictional effect accounts for the displacement of the two curves along the torque axis. (See Fig. 5 for typical torque vs. wind curve.) Since the radial force of the coils on one another is greatest in the region of full wind and since the radial force is, in effect, the normal force used in computing the force of friction, it would be expected that the greatest displacement should occur in this region. This is clearly shown on the illustrated torque curve. Isolating the effect of these frictional forces was one of the primary difficulties encountered while developing a satisfactory means for torque measurement.

A further difficulty encountered in the attempts to measure the torque output of a spring was that of obtaining the required accuracy. The degree of accuracy desired may be readily understood when it is realized that research is constantly being done to obtain non-setting and non-corrosive springs, which characteristics determine the spring life and breakage qualities. Inasmuch as the torque requirement of a watch movement is readily determined and has been found to be rather critical (for small watches a variation of a few gm-cm. is intolerable) the torque measurement on experimental springs should be comparatively accurate, especially when small changes in the alloy or in heat-

Fig. 1

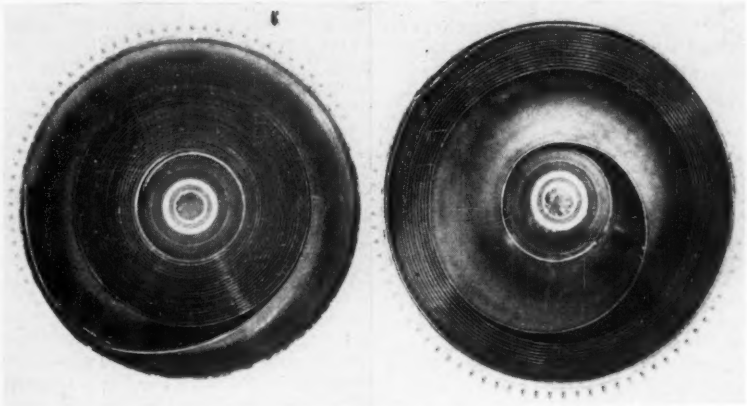


Fig. 2 Fig. 3

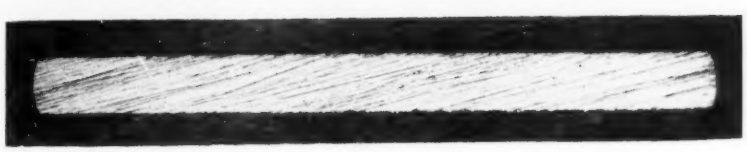


Fig. 4

*Patent has been applied for by E. Van Haaften, Superintendent of the Watch Research Department and assigned to the Hamilton Watch Company, Lancaster, Pennsylvania.

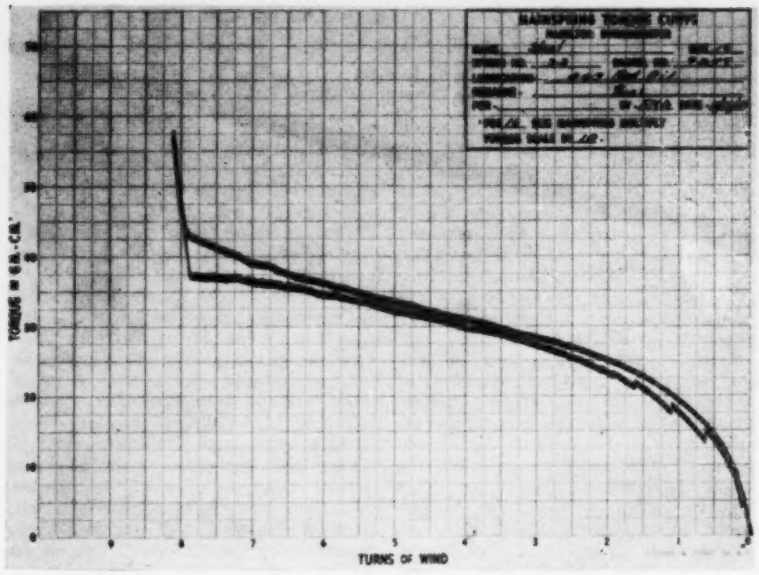



Fig. 5

treatment methods may determine the success or failure of these other research efforts.

Furthermore, it would be desirable to classify mainsprings on the basis of their torque delivery rather than on the basis of their thickness which is the accepted practice. Naturally the thickness of the spring has a decided effect on its torque characteristic but so does its hardness, free-sprung shape and quality of finish.

The time required to conduct torque tests on mainsprings was also a factor to be considered. Any method which is automatic and does not require the constant presence of a technician is more desirable than one which would necessitate the undivided attention of an operator throughout the testing time.

In brief, then, the difficulties encountered in any method of measuring watch mainspring torque output include (1) the sliding action of the coils along one another resulting in uneven unwind as a result of static and kinetic friction, (2) non-repeatability of torque delivery, (3) degree of accuracy desired as a result of other research efforts and for classifying mainsprings and (4) limited time available for conducting test.

Methods previously used at Hamilton for torque-testing mainsprings, while unsatisfactory in many respects, did provide information of value for the determination of the features which would be desirable in new test equipment. These may be summarized as follows:

(1) Duplicate as nearly as possible the actual working conditions of a mainspring in a watch movement.

(2) Results to indicate effect of surface finish of the spring.

(3) Results to indicate effect of lubricants applied to the spring surface.

(4) Results to be sensitive to slight changes in torque value due to alloy changes or modifications in heat treatment.

(5) Results to be repeatable.

(6) Operation to be fool-proof; that is, independent of the human equation.

(7) Automatic operation requiring technician's time for loading and unloading only.

(8) Time for complete test to be as short as practicable.

(9) Mainspring torque to be measured during both wind and unwind action.

(10) No computation or plotting of data to be necessary; results to be complete and direct-reading in whatever units are desired.

In order to accomplish the first requirement—that of duplicating actual working conditions—it was necessary to measure the torque directly at the barrel. It would have been desirable to wind and unwind the mainspring intermittently at the same rate as occurs in a watch. However, since the time element of approximately thirty-six hours (average time for a wrist watch mainspring to completely unwind in actual use) was excessive, for practical purposes it was decided to forego intermittent operation and use continuous wind and unwind, permitting the time of unwind to be equal to the amount of time the mainspring is actually in motion to completely run down when in a watch. The mainspring unwinds in a watch for approximately 0.003 sec. for each beat or half-oscillation of the balance wheel. Since most watches are five-beat movements (balance wheel making two and one-half oscillations per second) the total time the average wrist watch mainspring is in motion during its thirty-six hours of run down is 32.4 minutes. Using this figure for the run-down time, and also for the wind time, a close approximation to actual working conditions could be obtained and simultaneously the test time was reduced to something of practical value.

The remaining characteristics could be obtained if a method were devised for continuous and automatic recording of torque as the spring wound and unwound. The problem then resolved itself into two parts: (1) control the period of both wind and unwind to approximately 32 minutes and (2) record the torque values continuously throughout this period. The first part of the problem was easily solved for it meant simply using a motor drive which could be reversed automatically when the torque exceeded a predetermined amount. However, the second part required certain discrimination.

Heretofore, dynamometers used in the watch industry, according to available information, employed a calibrated spring. However, such springs had proved unsatisfactory for, even though they were made of the highest-quality steel and manufactured to close tolerances, they were not reliable over a period of time and did not possess sufficient accuracy over the wide range of torque necessary for testing many different size mainsprings.

However, another principle, that of a weighted beam, was chosen, permitting the use of fixed masses, the weights of which would remain essentially constant. The principle involved was essentially that of a "hunting" system, wherein a small weighted car placed on a beam, which was pivoted near one end, would be caused to move in a manner which would tend to keep the beam horizontal. To the one end of the beam would be applied, by means of a cord, the torque of the mainspring. As the torque increased, raising the beam-end, the car would move away from the pivoted point until it caused an equal and opposite torque. The car was to be controlled by a lead screw running the length of the beam through a nut fastened beneath it. Two difficulties immediately arose: (1) a means of controlling the direction of rotation of the lead screw and (2) a means of using the position of the beam to control this direction.

The first difficulty could not be conveniently overcome by any mechanical device. Since the beam pivoted, any connection to a motor placed elsewhere on the machine, such as a flexible shaft, would interfere with the balancing action, either directly or indirectly, by causing a change in the applied torque other than that caused by the moving car. Attaching a motor directly to the beam was unsatisfactory for two reasons: a motor of the required power and speed was too heavy to be located thusly and, in addition, it was desirable to have the motor which controlled the car also control the recording mechanism—which would again involve a system of coupling. A convenient method was found in the application of a pair of Selsyn motors, of the type formerly used in aircraft instruments. One of these motors was sufficiently small to be mounted on the beam across the fulcrum point from the car. By using these Selsyns, it was possible to connect electrically from the one which would be driven by a motor to the one on the beam, which would turn the lead screw. This method minimized interference with the balancing of the beam.

The second difficulty, controlling the

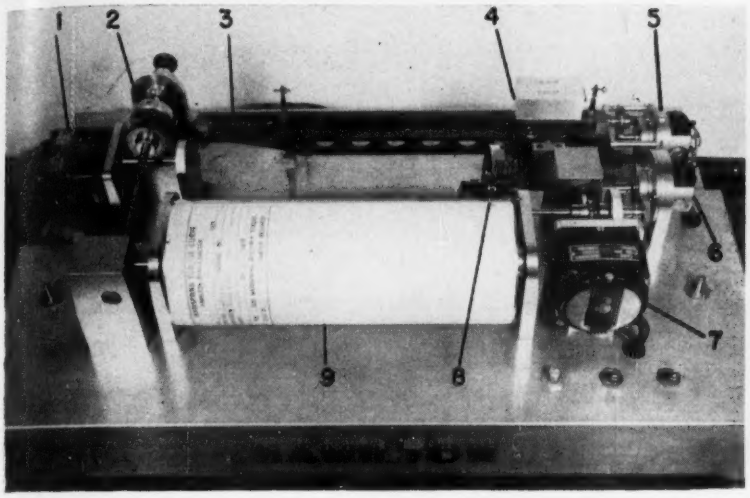



Fig. 6. 1. Mainspring wind motor; 2. Mainspring barrel holder; 3. Beam; 4. Weighted car; 5. Autosyn motor; 6. Autosyn transmitter; 7. Reversible motor; 8. Recording pen; 9. Recording drum.

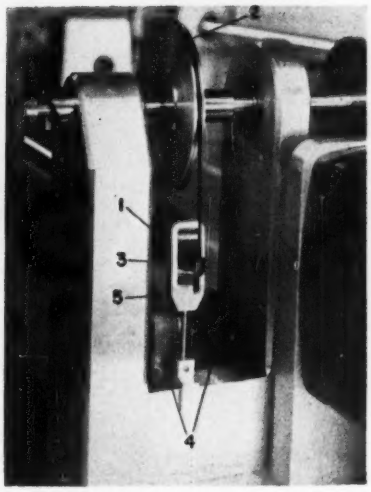



Fig. 7. 1. Beam; 2. Mainspring barrel holder; 3. Yoke; 4. Electromagnet; 5. Aluminum vane.

direction of rotation of the motor which would drive the lead screw, posed a greater problem. Heretofore, contacts had been used on similar beams which actuated controlling relays. However, contacts get dirty, corrode and constantly cause trouble, so a better method was sought. Two methods were considered: (1) variation of capacitance which would be determined by the position of the beam and (2) variation of inductance which could be controlled likewise. Both of these methods, however, would involve considerable experimenting, so it was decided to look for a commerically-made control system which could be adapted to the purpose desired. Such a system was found in the "Electrolink" which uses the change in a magnetic field to operate control relays. An adaptation could be made by placing a vane on the beam which would cut a magnetic field to a greater or lesser extent as its position varied.

With these essentials established, the rest of the design was completed. Its principal components were:

A motor to drive the barrel arbor, thus winding the mainspring;

A pivoted beam to which torque of the mainspring was applied;

A movable weighted car which located itself on the beam to counteract the applied torque;

A drive motor which moved the car along the beam through the intermediary elements of a Selsyn motor, follower and lead screw;

A control device which reversed the direction of the car drive motor at will depending upon the direction of unbalance of the beam.

The recording mechanism was designed after similar equipment already in use by incorporating a drum which revolved as the mainspring was wound and unwound and a pen which moved along the drum as the car was moved along the beam. A chart, commercial graph paper, could then be placed on the drum and the pen would trace out a curve the shape of which would depend upon the degree of wind or unwind of the spring and the position of the car as it moved to counteract the torque delivered by the spring.

A microswitch, controlled by a yoke placed over the end of the beam to which the torque was applied, operated a relay which would reverse the mainspring wind motor. In this fashion the spring would wind until the torque increased at a rate faster than that which the car could counteract; at which point the pull of the spring would be sufficient to cause the beam to lift the yoke, closing the microswitch and reversing the wind motor. The motor would then unwind the spring until the car returned to the pivot point.

### Principles of Operation

The actual arrangement used in the mainspring dynamometer to reproduce the foregoing system is shown in Fig. 8. Dynamometer beam 1 is the lever upon which the forces act. Its pivot shaft is mounted in jewel bearings. Cord C, held in a slot in the end of the beam by a knot, is fastened to barrel mounting disk B. A mounting disk provides means for holding the barrel stationary so that the barrel arbor can be rotated slowly, thus winding or unwinding the mainspring contained within the barrel. Dynamometer car 2 carries weight W. The car is propelled back and forth

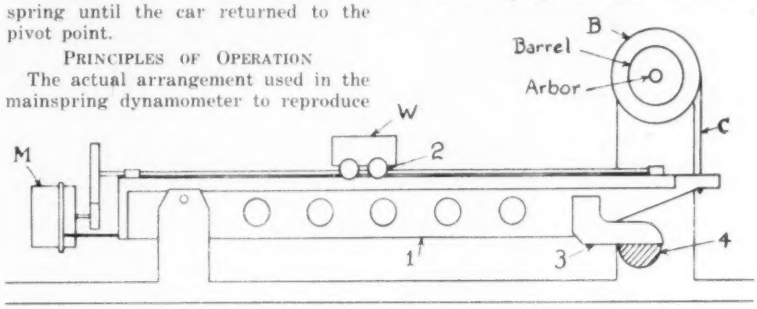



Fig. 8.

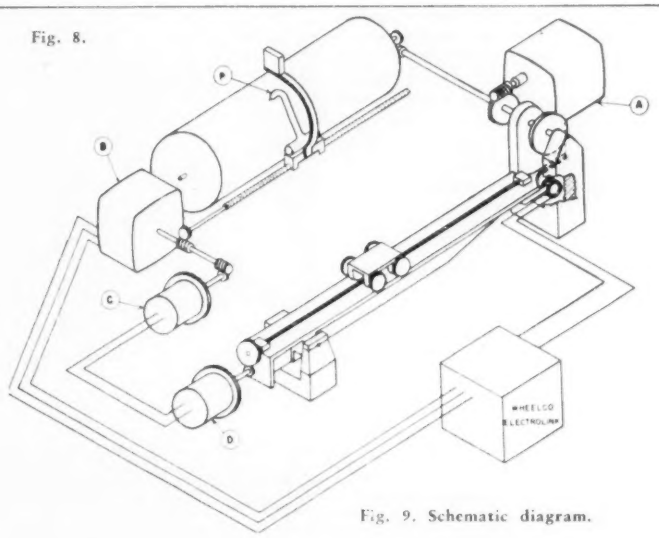



Fig. 9. Schematic diagram.

on the beam by the lead screw, which engages a split nut attached to the car. The weight is driven through a spur gear reduction by motor M, a Selsyn follower.

The control system, whereby the weight on the beam is caused to move in the necessary direction as soon as the beam gets out of balance so that the true torque of the spring is indicated by the position of the weight, is accomplished by an electronic control circuit which actuates a relay and reverses the motor driving the Selsyn transmitter. The Selsyn follower on the beam follows the movement of the transmitter very closely. As soon as the beam is out of balance, aluminum vane 3 on the beam moves in the field of electromagnet 4 in the electronic circuit. The resultant change in the flux field of the magnet acts as a signal to the electronic circuit to actuate the relay, thus reversing the motor and thereby the direction of travel of the weight.

Reference to the schematic diagram, Fig. 9, will show the relation of the major components of the dynamometer for recording the torque delivery of the winding or unwinding mainspring. Since it is desired to record the torque delivery of the spring on rectangular coordinates, one of the axes of the graph paper represents torque and the other represents the number of turns of the mainspring arbor. Motor A turns slowly at a constant speed and drives the arbor shaft through a worm-gear reduction, thus winding the mainspring. The same shaft revolves the recording drum through another worm-gear reduction. Consequently, the recording drum speed is proportional to the mainspring arbor speed. The mechanism is designed so that a unit distance along the circumference of the drum represents one turn of the mainspring arbor. This is the abcissa of the graph, which is represented by the circumference of the drum.

The ordinate of the graph is scaled to measure torque. High-speed reversible motor B is the unit controlled by the Wheelco "Electrolink"—the electronic control device. It drives the lead screw at the recording drum through a worm-gear reduction, causing recording pen P to travel parallel to the axis of the drum. This same motor also drives Selsyn transmitter C through another worm-gear reduction. The electrical connection between Selsyn transmitter C and receiver D serves as a means for transmitting rotation to the lead screw on the beam. Thus, the pen travels along the surface of the drum at a speed proportional to the speed of the dynamometer car on the beam. The design of the system determines the relative magnitude of these speeds and thus the scale of the torque axis.

### Mechanical Construction

The photographs (Figs. 10-12) show different views of the dynamometer and illustrate the actual appearance of the various components of the machine.

There are many features of the dynamometer that, so far, have not been explained. Some of these are not absolutely essential to the actual operation, but serve as safety devices or means of preparing the machine for automatic operation.

Main switch A of the dynamometer shown in Fig. 10 supplies electric current to all parts of the assembly except the "Electrolink." "Electrolink" switch B is located alongside the main switch. Starting button C, pictured in the same group, is depressed when it is desired to start automatic operation.

The two safety switch lever retainers located alongside the dynamometer beam, as shown in Fig. 11, are placed to prevent the dynamometer car from jamming against the lead screw bearing supports and damaging the lead screw or the split nut. This arrangement also serves to prevent pen holder 1 from damaging its lead screw by striking and jamming against the supports of the recording drum. The safety switches are in series with the main switch so that when they are opened, all operations cease immediately. The safety switch striker, which extends from the side of the dynamometer car, strikes these switches when the car travels too far on the beam.

There is also a switch which serves to reverse motor $M_1$ when the mainspring is fully wound. This switch ($S_R$) is shown in Fig. 12. When the mainspring is fully wound, the tension in the cord attached to the slot in the end of the beam exceeds the torque produced by the car and causes the beam to push up against the top sleeve in the yoke and close this reversing switch. By closing the switch for an instant, relay 2 ($L_2$) is actuated. The relay acts to reverse motor $M_1$ which allows the spring to unwind slowly. The reversing switch opens again, once the spring begins to unwind, but the motor is kept running in the reversed direction because the relay completes its own circuit after it is initially energized.

The two reversible motor switches ($S_1$ and $S_2$), shown in Fig 10, are double-throw switches which are used to operate their respective motors in either direction for the zero positioning of the mainspring assembly and car. Their operation is entirely independent of the "Electrolink" and they are eliminated from the circuit when automatic operation is started.

The pen holder, with its half-nut, simply rests on its lead screw, since it is necessary to remove it at the completion of each test. The pen point is held against the graph paper by virtue of the position of the counterpoise weight attached to the pen holder. The ink supply for the pen is carried in the glass cylinder which is an integral part of the pen.

Knurled knob 2 is used to position the pen on the graph paper more exactly after the pen holder has been placed on the lead screw. In

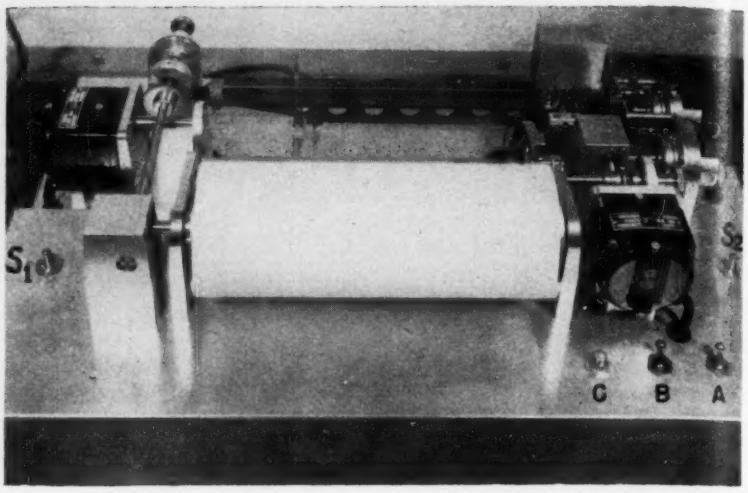



Fig. 10

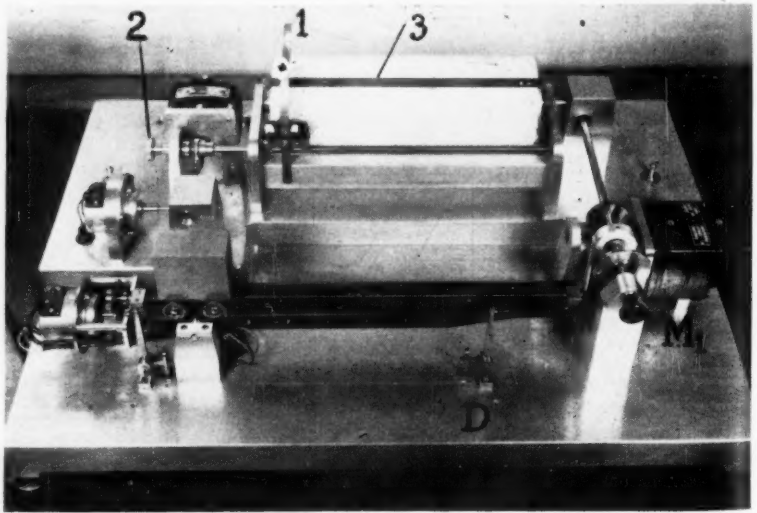



Fig. 11

order to position the pen in this manner, a friction clutch built into the worm-wheel mounting allows the lead screw to be rotated without turning the worm wheel. Another friction clutch is located at the worm-gear reduction unit for the drum and is mounted inside the end support and cannot be seen. It makes it possible to revolve the drum by hand in order to wrap the graph paper around the drum and to position the drum correctly before starting the machine.

Certain parts of the machine must be changed whenever a different size mainspring is to be tested. They consist of the weight, which is placed on the dynamometer car, the barrel mounting disk, the barrel clamping ring and the barrel centers.

Steel strip 3, shown in Fig. 11, is snapped into place to hold the graph paper tightly on the recording drum.

## Electric Circuits

A further understanding of the principles of operation of the dynamometer and its general construction can be gained by referring to the electric circuit diagram, Fig. 13.

To supply electric current to the entire unit, both the main switch ($S_1$) and the "Electrolink" switch ($S_2$) must be closed. The two safety switches ($S_6$ and $S_7$), shown in series with the main switch, must also be closed before any operation of the machine can start.

After the initial positioning of the drum, pen, car and mainspring arbor, automatic operation of the dynamometer is started by pressing starting button $S_3$. This allows the relay 1 ($L_1$) to be energized. Examination of the circuit of this relay will show that as soon as it is energized, its own contacts complete the circuit, so that only a push button is needed to start the operation. Closing this relay also supplies current to the center pole of relay $L_3$ in the "Electrolink". By examining the circuit at relay 2 ($L_2$), it can be seen that when the starting button is depressed, this relay remains open; thus, the poles in contact at this time complete the circuit to the arbor drive motor so that it will turn the barrel arbor in the direction necessary to wind the mainspring.

The position, at this time, of the vane in the field of the electromagnet, determines the initial direction of rotation of the pen-drive motor. The flux density in the magnetic field depends upon the position of this aluminum vane. The signal from this source is applied to the grid of the first stage of a twin-triode. The resulting amplified signal in the plate circuit of the first stage is applied to the grid of the second stage for further amplification. Then, the current in the plate circuit of the second stage is used to actuate relay $L_2$. A portion of the amplified signal is also fed back to the grid of the first stage so that a high degree of amplification is obtained. The fluctuation in plate current, caused initially by the movement of the aluminum vane, serves to open and close the relay and thus alternately reverse the pen-drive motor which causes the dynamometer car to move back and forth on the beam. Since the circuit to the motor is such that it is always turning in one direction or the other, there can be no neutral position of the vane in the magnetic field. Movement of the beam causes the vane to move into or out of the magnetic field, changing the flux density which causes the electronic circuit to actuate the relay and reverse the motor. As a result of this type of circuit, the weight on the beam continually seeks an equilibrium position and displays a "hunting" motion, the magnitude of which depends upon the various physical and electrical characteristics of the machine.

As soon as the mainspring is fully wound, the tension in the cord attached to the end of the beam exceeds the torque produced by the car and causes the end of the beam to push against the yoke with such force as to close microswitch $S_8$ leading to relay $L_2$. This action allows the relay to be energized (and held closed by its own circuit) and to reverse the direction of rotation of the mainspring arbor drive motor, thus allowing the spring to unwind. None of the other actions of the machine is affected by this occurence, and the machine continues to operate until the spring is unwound.

Examination of the circuit will show why switches $S_4$ and $S_5$ which can be used to operate the two reversible motors are only effective when the machine is not operating automatically. When the main switch is closed, and before the starting button is pressed, the circuit to the center poles of these switches through first relay $L_1$ is still complete. However, when the starting button is pressed, energizing relay $L_1$ breaks this circuit and renders the switches ineffective.

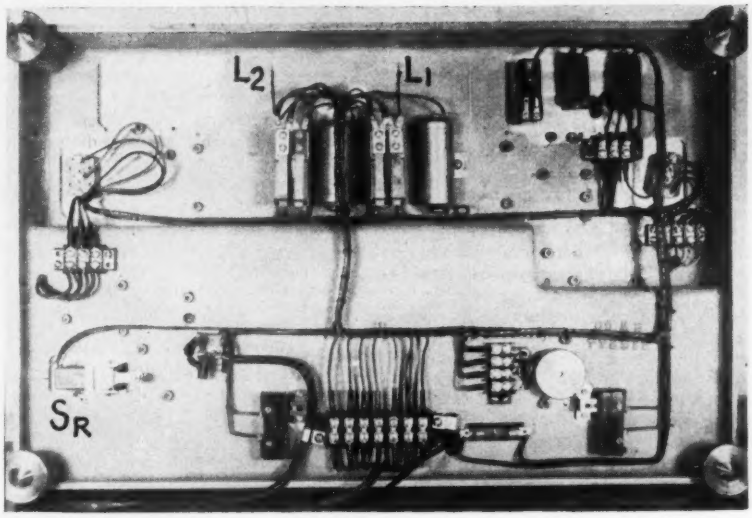



Fig. 12

## Test of Equipment

Prior to analyzing the results obtained from the use of the dynamometer, several tests were conducted to determine the reliability of the data.

One of the important facts to be remembered about the recorded dynamometer result is that it is a record of the dynamic torque delivery of a mainspring assembly as it is being unwound. This more nearly duplicates the actual torque characteristics of the mainspring in a watch under ordinary running conditions than the testing methods which measure the static torque of the spring assembly. Because of the time element involved, the process of winding and unwinding the mainspring in the barrel has been distorted in that, while for a railroad size watch the winding operation requires approximately 30 seconds and the run-down time is about 50 hours, in the dynamometer each of these processes require 30 minutes.

The question arose concerning the effect of this time distortion on the resulting torque curves. The wind torque curve is not so important as the unwind torque curve because it does not have any direct influence on the balance motion, or amplitude of oscillation, but only serves as an indication of the efficiency of the assembly. Therefore, it was decided to alter the dynamometer so that the speed with which the arbor rotated was reduced 100 times. With this reduction gear arrangement the unwind time was lengthened from half an hour to 50 hours, which is the approximate run-down time for a mainspring in a railroad watch.

A 16 size (railroad size) steel mainspring was tested under these conditions and then at the regular speed. The torque curve of the retarded test followed exactly the same pattern as the regular run but gave a somewhat different appearance because of the wider hunt line of the former. The narrower regular test ink line lay within the retarded test curve throughout its length. It is thus apparent that the energy output is not altered by the rate of wind and unwind used when testing a mainspring on the dynamometer under the designed conditions.

As a check on the probable effect the speed with which the spring is ordinarily wound may have on the torque delivery during the unwind process, the spring was wound by hand at approximately the rate used when winding a watch and then tested at the retarded speed for the rundown period. The resulting torque curve followed the pattern and position of the complete retarded test. In so far as can be determined, the speed of the wind has no discernible effect on the resultant unwind characteristics.

The other part of the dynamometer mechanism which posed a question as to its effect on the result recorded was the speed of the Bodine motor used to drive the car and recording ink pen. As designed, a 1200-rpm motor is used which results in an ink line of approximately 0.1 in. width. Experiments were made with an 1800-rpm. motor and an increased width of the recorded line resulted without improving the sensitivity of the equipment. For the other extreme, by means of a 60-rpm. motor and a step-up gear ratio of 1 to 2, the resulting shaft speed was reduced to 120 rpm. This latter ar-

rangement reduced the speed of the car and pen to the extent that there was very little hunting and, therefore, practically a single line curve. This would be desirable except that approximately a turn and a half at the beginning and the end of the unwind curve could not be recorded because the reduced speed of the car prevented balancing of the rapid increase and decrease of torque. The narrow torque curve lines coincided with the regular test curves—an indication that the mean of the regular test ink line is a good indication of the torque characteristics of the mainspring.

The ultimate reason for testing any mainspring is to determine as nearly as possible the energy which it would supply to a watch as indicated by the resulting balance motion. It is necessary, therefore, to establish the relationship between the torque curve recorded and the torque supplied by that spring in a watch. The most desirable condition would be one in which the torque reading from the dynamometer recorded results would be an actual reproduction of the wind and unwind characteristics of the mainspring when used in a watch.

Data were needed before a comparison could be made—the torque chart for the mainspring, the torque-motion curve for the watch, the wind-motion curve for the spring in the watch, and the theoretical wind-motion curve as plotted from the first two curves.

Four 16-size Model 992B railroad watches were tested for mainspring torque requirements according to an established laboratory procedure. The torque required to produce motions from half a turn to 1¾ turns in increments of one-eighth turn was plotted for each watch. The torque curve for each mainspring was obtained from a dynamometer test prior to being placed in the watches for the wind-motion tests. In the wind-motion test the balance motion was recorded for each half-turn unwind of the barrel from full wind to run-down. Following this, the theoretical wind-motion curve was superimposed on the actual wind-motion curve so that a comparison could be made.

The theoretical wind-motion curve was established by reading the torque value for the mainspring at each half-turn down from the dynamometer results, locating this value in gram-centimeters on the torque curve of the watch and reading the motion which should result. This motion was plotted on the wind-motion graph against turns down of the arbor.

At least two springs were tested in each of the four watches and the greatest variation between the actual and theoretical wind-motion curves in each case was less than one-eighth of a turn of balance motion. Inasmuch as three independent tests were conducted and four separate operations performed in arriving at these results, it is obvious that the accumulation of those probable errors involved in each step could cause a discrepancy of this magnitude.

From the data obtained as a result of this analysis, it became evident that the original purpose for which the mainspring dynamometer had been designed was fulfilled. It provided a simple and accurate means of torque-testing mainsprings, providing a record from which significant information relative to the entire mainspring and barrel assembly could be derived.

### Analysis of Results Obtained

Upon the completion of the construction and testing of the machine, a thorough analysis was made to determine what information could be obtained from the resulting torque curves, an example of which is shown in Fig. 5, and to isolate the various factors which would influence the torque output of the mainspring.

The analysis was divided into two parts: (1) explanation of irregularities of the curves and (2) correlation between torque values recorded and the energy actually released by the spring under normal conditions in the watch. Since the mainspring is always used as an assembly, the effect of each one of the parts of the assembly had to be considered.

One of the most frequent occurrences on the torque curves recorded during the preliminary testing of the dynamometer was the cyclic rise in the torque values during the winding operation and a corresponding drop in the torque available during the unwinding operation, which resulted in "bumpy" torque curves.

The nature of the distortion of the curves suggested that the "bumps" recorded were periods of increased friction caused by some irregularity of one, or a combination of several, of the parts in the mainspring assembly occurring at regular intervals as a result of the winding and unwinding action. The various parts of a mainspring assembly were examined and the following points were suggested for investigation:

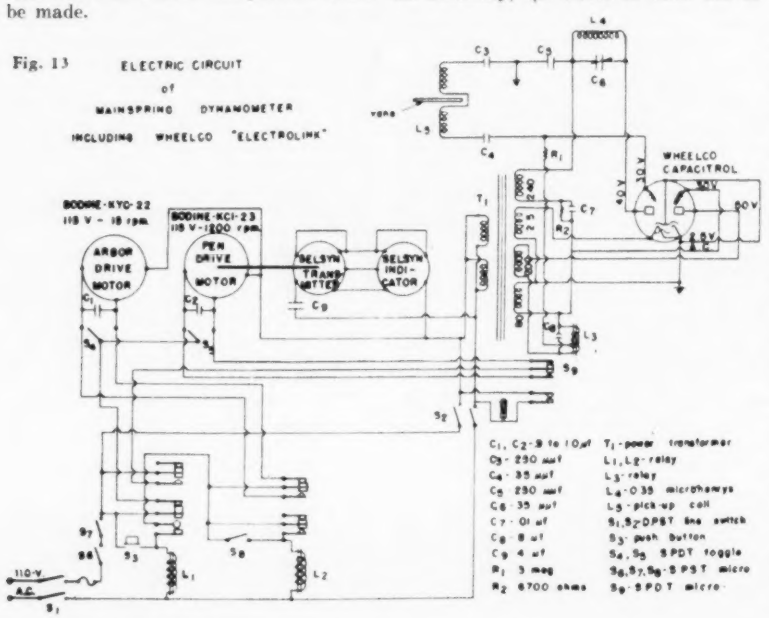
1. Smoothness of finish on inside of barrel and cap.
2. Hardness of finish on inside of barrel and cap.
3. Trueness in the flat of the barrel and cap assembly.
4. Fit of the arbor in the barrel and cap.
5. Shape of arbor and its effect.
6. Surface finish of the mainspring.
7. Edge finish of the mainspring.
8. Camber over length of spring.
9. Formation of inner terminal and its fit on the arbor.
10. Trueness in the flat of the inner terminal.

Each of these items was investigated in turn. It was learned that although each of these items had a decided effect on the smoothness of the torque curves, the greatest offenders were trueness of the inner terminal and quality of finish of mating surfaces. An interesting side point was the dependence of spring efficiency on this quality of finish. This efficiency is indicated by the space between the wind and unwind curves and has been found to be very sensitive to sliding friction—more so than had previously been suspected.

In general, however, the various experiments showed that the transmission of force depends not only upon the quality of the various parts involved but also upon the way the spring is housed in the barrel. The mainspring must be placed in the barrel carefully and the inner terminal seated correctly on the arbor; the spring must be lubricated correctly over its entire length; the barrel must rotate freely on the arbor; and there must be sufficient clearance between the edges of the spring, cap and barrel as well as sufficient arbor endshake. Each of these factors has a direct effect on the efficiency of the assembly, and the evenness with which the energy is released as indicated on the dynamometer chart.

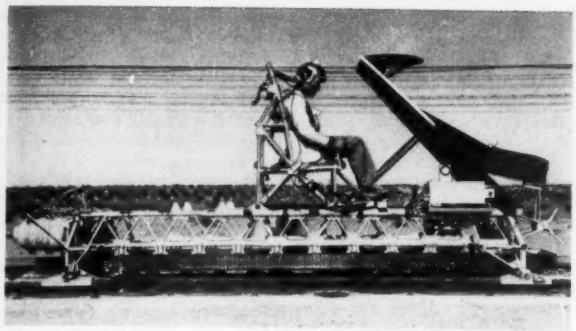
Testing and analyzing the dynamometer has served to provide the Hamilton Watch Company with information heretofore unattainable although, in some cases, suspected. The machine has provided a means whereby critical testing of mainsprings is possible and has resulted in the production of mainspring assemblies having even flow of power and greater efficiency.

Fig. 13 ELECTRIC CIRCUIT of MAINSPRING DYNAMOMETER INCLUDING WHEELCO "ELECTROLINK"




C1, C2 - .5 to 1.0 μf
C3 - 230 mmf
C4 - 35 mmf
C5 - 230 mmf
C6 - 35 mmf
C7 - .01 μf
C8 - 8 μf
C9 - 4 μf
R1 - 3 meg
R2 - 6700 ohms
T1 - power transformer
L1, L2 - relay
L3 - relay
L4 - .035 microhenrys
L5 - pick-up coil
S1, S2 - DPST line switch
S3 - push button
S4, S5 - SPDT toggle
S6, S7, S8 - SPST micro
S9 - SPDT micro

# SLEDDING ON THE MOJAVE



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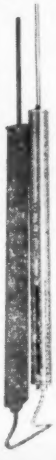

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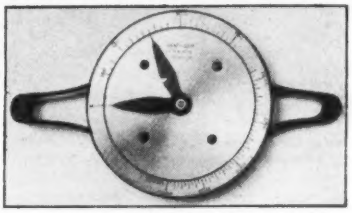

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# The Relationship Between Engineering *and* Inspection

By CHARLES B. JOHNSTON, Chief Engineer, Pittsburgh Equitable Meter Div., Rockwell Mfg. Co., Pittsburgh, Pa.

TODAY, the relationship between Engineering and Inspection is somewhat complex and probably not as well understood as it should be. They could both be classed as sciences. Neither is an end in itself but is rather a means to an end. That end is the rapid assembly of units or mechanisms that will function correctly over a reasonable period of time, present an attractive appearance, with a cost low enough to be competitive in the open market and that can be serviced with little difficulty. Many tools are available to both for use in achieving this end. Probably the engineer is the better equipped at present, because he has had easier access to the voluminous literature on many subjects. Societies have been in existence for years where he could meet his contemporaries and exchange ideas. Laboratories have been available for his experimentation, in which he could build models and prototypes, conduct exhaustive tests and choose the best methods and materials.

The Inspector has been handicapped in this respect. Although it is true that he does have many types and kinds of instruments available now for the proper performance of his tasks, their availability is comparatively recent and has been brought about by the demand for mass interchangeable production.

Unfortunately, there has been no place where he could meet and exchange ideas with others engaged in similar work. The organization of this Group in the ISA affords him this opportunity, and it is hoped every inspector will avail himself of it.

In present-day manufacturing the importance of the relationship and cooperation between the Engineering and Inspection Departments is generally recognized as essential in the manufacturing of an article that will be competitive in quality and price.

The Engineering Department is expected to provide a service to the Sales and Manufacturing Departments. To Sales, this service provides items that are so designed as to be competitive functionally, present an attractive appearance, and priced so that they will be readily saleable. To Manufacturing, this service is extended in the form of drawings, specifications, material lists and other information which will control the manufacture of the unit to be produced. Inspection receives the same service and information as Manufacturing, quite frequently, however, in greater detail.

Inspection supplies a service to both Engineering and Manufacturing: To Engineering in maintaining the integrity of the product as required by the various drawings, specifications, and other required information. To Manufacturing in the interpretation of the information supplied by Engineering, the maintenance of quality in rough and finished material purchased from outside vendors, together with the policing of the actual manufacturing operations and the measurements required by them.

That this relationship is ancient, and that definite measurement has existed through the ages is shown by the construction of such works as the Pyramids, the Ark, or King Solomon's Temple in biblical times. I do not believe that the best of our present-day contractors would attempt the construction of any of these units without engineers and inspectors. It is a foregone conclusion that some definite design was followed and that measurement was referred to an established standard. Just what that standard was is vague and controversial. To complete these projects, many engineers and a large corps of inspectors must have been necessary, because the labor was performed by slaves. We may assume that engineering was sound and that measurements and standards were rigidly enforced by "inspectors" (probably not known as such).

Today, quality products are produced

*Presented before Pittsburgh Inspection and Gaging Sub-section, ISA, March 14, 1950.


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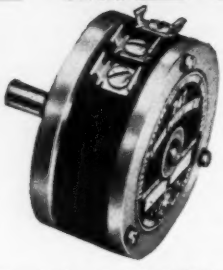

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The real relation between engineering and inspection was confused all through the middle ages. This was caused by the lack of reliable and satisfactory standards of measurement. Three barleycorns taken from the middle of the ear and laid end to end would not make a very reliable inch, yet this was used in England in 1324. My sympathies to the inspectors who had to use them!

Up to 1866 the English yard was in general use in this country. In 1866 the meter and the remainder of the metric system were adopted by Congress as our standard.

The primary standard of length in this country today is the National Prototype Meter No. 27, similar to the International Prototype Meter kept at the International Bureau of Weights and Measures near Paris.

The necessity for some standards and correlation between scientific investigation, engineering and production work has been recognized for many years. Strangely enough, war has been the medium which has given the greatest impetus to this work.

It is noteworthy that the American Society of Mechanical Engineers felt it necessary to establish standards of limits, fits and tolerances for use by both engineers and inspectors many years ago. These were widely distributed and generally accepted by industry. This work is now being carried on by the American Standards Association, the Manufacturers Standardization Society, the American Society for Testing Materials, and several others. Every engineer and inspector today is probably using the standards and methods established by these societies either knowingly or otherwise.

In 1798 Eli Whitney, inventor of the cotton gin, established a gun factory for what was then mass production. As there was no agreement on foot-rules, he as an engineer, adopted one, and his designs, machines and gages were built around it. He achieved what was a remarkable degree of success at that time because his engineering, manufacturing and inspection were under rigid control. Nevertheless, parts made in other plants were not interchangeable with his, because his standards were not adhered to. With each succeeding war, standards have been refined and generally adopted, until today we have certain standards that engineers and manufacturers in all countries are familiar with. The recent adoption of a common screw thread by England and the United States is a notable indication of the trend today.

In a manufacturing plant employing up-to-the-minute methods and engaged in the active production of reasonably standard items, the Engineering Department will be providing service through a Chief Engineer, with Project Engineers, Junior Engineers, Draftsmen, Chemists, Metallurgists and laboratories under his direction. The Department will usually be so organized that the Project Engineers relieve him of a major portion of the detail work. They will furnish Inspection with information on new and changed drawings, advance information on new products, test procedures and performance requirements, together with reports on incoming materials. They will receive from Inspection reports on sub-standard material, dimensional inaccuracies, improper functioning of finished items with suggestions as to improvements.

The Inspection Department will be providing service through a Chief Inspector, who will be relieved of detail work by Section or Assistant Inspectors, they in turn having line inspectors, parts inspectors, raw and finished material inspectors under their guidance. They will request from engineering, drawing interpretation, salvage information, deviations and changes to facilitate production, information on repairs and tolerances on tools and gages.

The similarity of the two departments is readily apparent by glancing at their respective organization charts. The staff of the Chief Engineer would consist of Project Engineers, Chief Chemist, Chief Metallurgist and Chief Draftsman; that of the Chief Inspector would comprise Section Inspectors, Test Supervisor, Raw Material, and Finished Product Inspectors.

Quite frequently you will find the Chief Engineer and Chief Inspector on different levels of the company organization. The Chief Engineer usually reports to top management and has a

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voice or vote in determining some of the policies; the Chief Inspector, however, in most cases reports to the Factory Manager, Superintendent or the Chief Engineer. If such a condition prevails, he obviously is at a disadvantage. It is not intended to decide here where either should be placed, but rather to show their relationship.

The Chief Engineer relies on his Project Engineers for the supervision of those men working on his projects. He in turn directs their activities toward design, supervision, adequate specifications for materials and testing. The Chief Inspector operates in a similar manner through his assistants or section inspectors. These men are usually in close contact with the supervisors of the different departments, the departmental foreman, as well as the different sections of the Engineering Department.

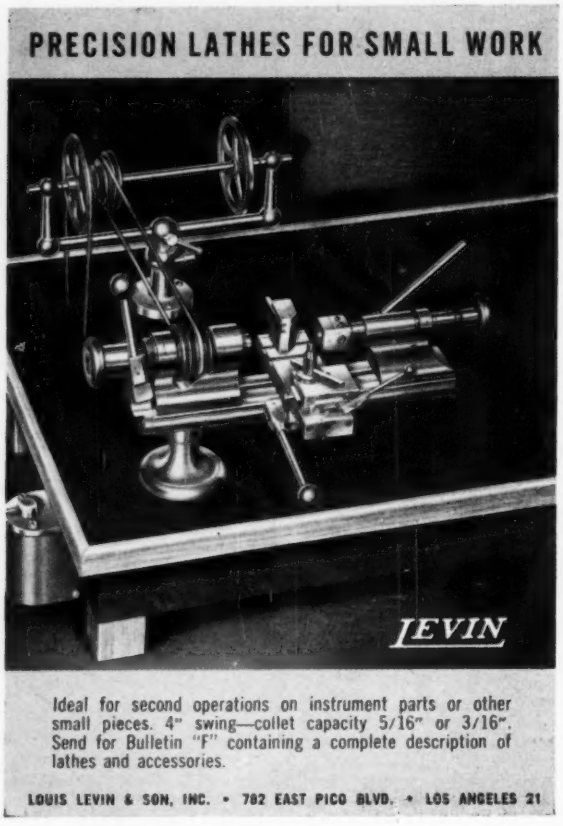
A like situation will be found in the Finished Products Section of the Inspection Department. These inspectors will be supervising the testing and/or proving of assembled units to insure performance requirements being met, making sure that the proper materials were used and that the finished unit has been properly painted, crated or otherwise prepared for shipment. A comprehensive knowledge of the item or unit being produced is a definite requirement of this section of the Inspection Department. We might compare the activities of this group with those of the Project Engineers. The two groups should, and usually do, cooperate fully. They have an important part in all manufacturing operations and the success or failure of this operation is largely determined by them.

The training of personnel for either of these groups requires tedious and painstaking attention to detail. Neither group is the place for inexperience or immaturity. Personal experience in both groups has taught this. As an example, shortly after graduation, I found it expedient to accept a position as Parts Inspector. I was given a blueprint, micrometer, gages and all other necessary equipment, together with several tote pans of small parts; and told to inspect them. After about two days of more or less industrious application I noticed another chap working on the same parts. Inquiry revealed that he was reinspecting the parts some "greenhorn" had rejected. I was the "greenhorn."

My first experience in an Engineering Department was similar. After completing my first assignment I saw another draftsman reworking drawings. Inquiry here disclosed that it was easier to rework them than to get it done by the one who had "messed" them up. There was no doubt as to who was guilty, as there were only five of us in the department. I cannot stress too strongly the point that section inspection or project engineering is no place in which inexperience can be given a free hand, because in these two sections the similarity is great and the opportunity for sound judgement is limitless. It is always interesting to note and compare the size of familiar objects with those seemingly abstract things shown on engineering drawings —dimensions and tolerances. How many inspectors, using micrometers and/or gages so deftly, have thought of the tolerances necessary to provide the reliability they depend on? The product they are inspecting can be only as reliable as are the tools used for inspection.

What dimensions and tolerances would an engineer place on the details of the instruments he uses and what would be the costs of the finished article? Each time a draftsman places a tolerance on a dimension and a checker checks it, the question should be mentally asked: "If this tolerance is not maintained, will the part be scrapped?" If the answer is "Yes," the tolerance should remain as established. If the answer is "No," the tolerance should be increased until the answer is "Yes." By doing this the work of the inspector will be made easier, cost reduced and his respect for the Engineering Department deepened.

When the Line or Parts Inspector checks a part, and the tolerance is found to be exceeded, his question should be: "If this part is assembled in a unit, will the functions or serviceability be affected?" If the answer is "Yes," it should be rejected. If the answer is "No," it should be passed.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He must be absolutely positive in his decision for if he is wrong and the unit fails in service, the wrath of the entire organization will fall on his shoulders. Knowing this, his immediate reaction is to reject it, saying, "It doesn't agree with the blueprint." This course is the easiest, but falls short of being the best. An inspector will usually find himself confronted with three kinds of rejections: (1) the part will be so far off dimensions that it is outright scrap. This one causes him no concern. (2) Those that can be reworked and brought within tolerance. These are usually returned to the offending department for rework and he has no difficulty here. (3) Those that may or may not be salvaged without lowering the quality of the product. The usual procedure is to consult Engineering and Manufacturing as to their thinking. Inspection should reserve the right to make the final decision in order to maintain the integrity of the product. Engineering will no doubt try to maintain quality and Manufacturing will be interested in reducing scrap losses and meeting production schedules.

Rough Stock and Incoming Material Inspection has the responsibility for the initial or preliminary inspection of castings, forgings and other materials. Here again cooperation between Inspection and Engineering is necessary. The inspector probably has to rely on the Engineering Laboratories to supply him with information as to chemical and physical properties, nondestructive tests such as x-ray or gamma-ray inspection. The Engineer (more or less of a perfectionist) is likely to be too critical while the inspector with a lively appreciation of production needs may be too lenient. There are dimensions on the average casting or forging that are unmachined, which could vary considerably without affecting the useability of the part. Yet a dimension is necessary. Probably everyone has encountered this condition at some time. What happens is this: The draftsman puts on a fractional dimension, stamps the drawing or fills in a tolerance block which says "fractional dimensions may vary plus or minus 1/32 of an inch" and releases it. The pattern or die shop takes full advantage of this and the rough part is received off dimension to a greater or lesser degree. The Inspector in a quandary finally decides to release it, only to find that probably the Tool Design Department has decided to use that particular spot as a rough locating or holding point. Trouble ensues; tools must be revised; production is held up; the supplier irritated; costs are increased—and the inspector is criticized. In the future he rejects everything not to dimension. The obvious remedy is for the Engineering Department to be as lenient as possible when dimensioning and for both Engineering and Inspection to consult with the Tool Design Section frequently, especially on new products. Then inspection can act confidently and the necessity for consulting Engineering will be lessened.

As previously mentioned, the quality of certain materials is usually a joint responsibility of Inspection and the Engineering Laboratories. This is true where non-destructive testing or inspection is employed. Chemical and physical properties are determined in the laboratories usually because equipment and trained personnel are available.

A close similarity exists between the Engineering Laboratories and the Standards Section of Inspection. The Laboratories set specifications for materials, and establish Standards which they expect to be maintained. The Standards Section maintains gage blocks, masters and the necessary equipment for measuring and checking not only their own tools, but also the jigs and fixtures used in production.

When the Engineering and Inspection Departments cooperate fully, the results they secure are very gratifying. Production moves smoothly and probably the organization prospers. When they get beyond the stage of friendly enemies the confusion and indecision that results is disastrous and management quickly takes steps to alleviate this condition.

In my opinion the two departments are wholly similar in their organization, responsibilities and duties. In actual practice they appear to be always on opposite sides and tolerating each other only because it is necessary. While it appears impossible at times to cooperate with them, the fact remains that dismal failure will be the result without them. Consequently we are "stuck" with both of them.


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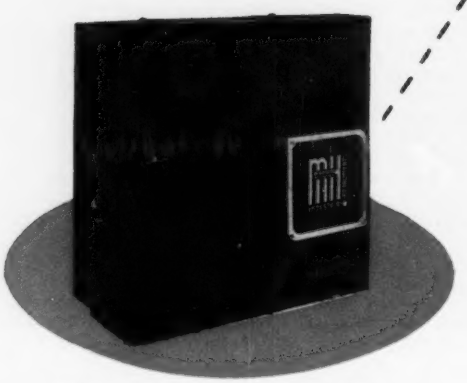

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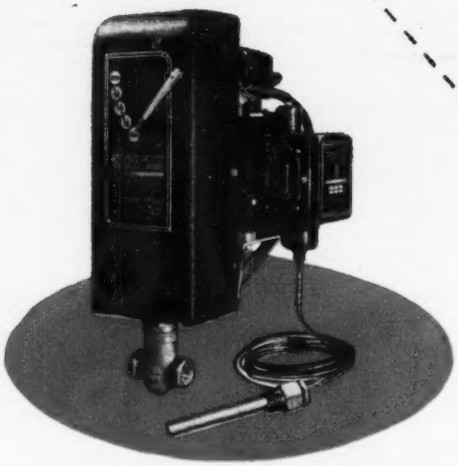

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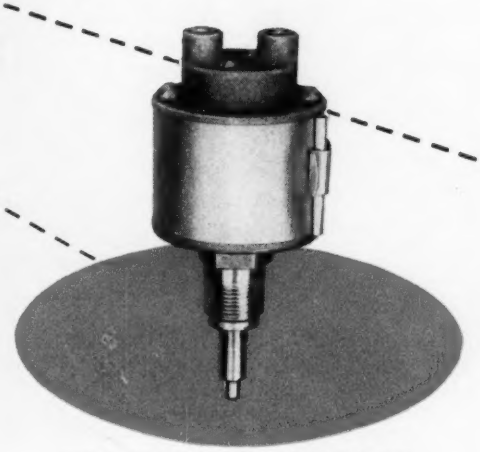

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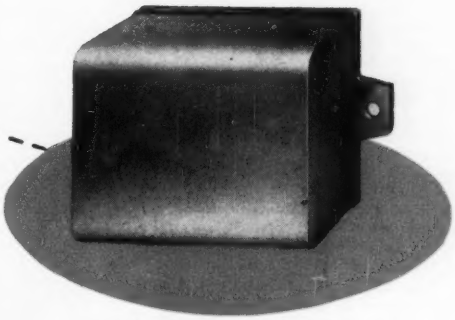

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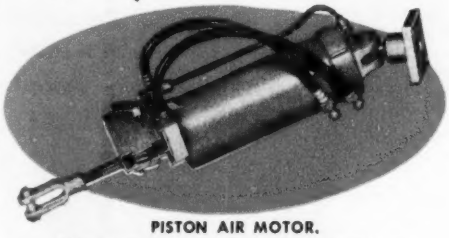

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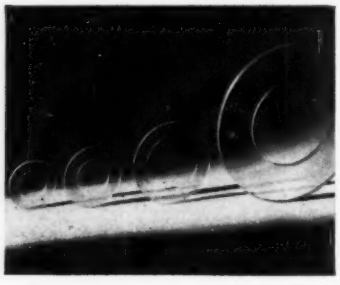

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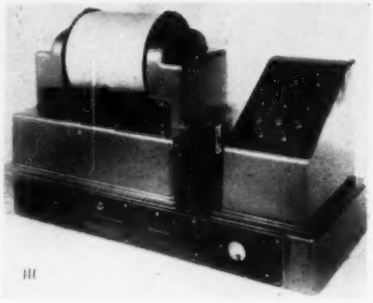
New "Model 21" double-beam infrared spectrophotometer with a wider range of operating variables than earlier commercial models records directly in percent transmission against a linear-wavelength scale on large, easily read charts. Instrument's resolution is up to limitations imposed by Raleigh criterion and Johnson-noise. Its speed of scanning ranges from 3 minutes to 100 hours for rock-salt region. Wavelength-drive speed can be

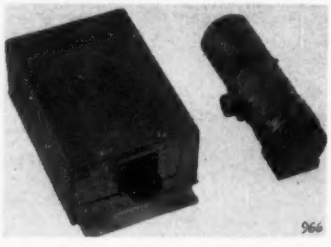


suppressed automatically when desired. Time of response varies from a few seconds to more than a minute for full-scale deflections. Over-all range of instrument is from less than 2 microns to 15 microns in rock-salt region. Chart scales are uniform from 1 to 50 inches per micron by integral factors. Chart size is about 32 by 11 in. Instrument is 40 by 22 by 20 in. Amplifiers and power supplies are external.—*The Perkin-Elmer Corp., Glenbrook, Conn.*

**Mention No. 404 when filling out card.**

## High-speed Remote-positioning System

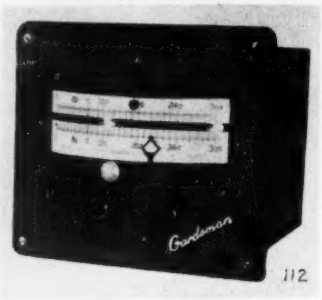
New aircraft system eliminates overtravel in high-speed remote positioning of throttles or jet after-burner valves. Designed for speeds up to 90 degrees per second, actuator rapidly approaches desired setting and then "hunches" to exact position. System consists of a control cabinet and actuator designed to meet all applicable AN requirements.—*Barber-Colman Co., Rockford, Ill.*



**Mention No. 405 when filling out card.**

## Pyrometer Controller

New "Model J Gardsman" pyrometer controller features all-welded construction of indicator unit, plug-in attachments, and narrow-range on-off positions. Over 30 standard ranges

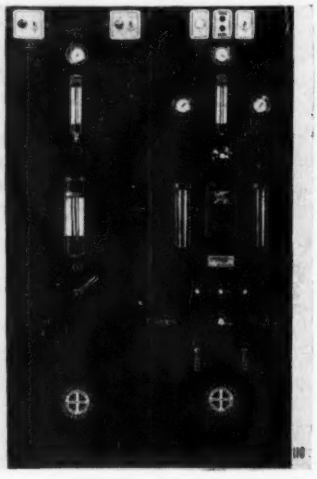



are available. Scale length is 5 in. Lowest potential sensitivity is 10 mv., and lowest current sensitivity 125 microamps. Accuracy is 0.75 percent of full scale. Contact rating is 4 amp. at 115 v., or 2 amp. at 230 v. 60 cps., non-inductive load.—*Taco West Corp.*, 525 *N. Noble St., Chicago* 22, *Ill.*

**Mention No. 406 when filling out card.**

## Carbon Monoxide Recorder

New improved model carbon-monoxide recorder is composed of a drier, analyzer and potentiometer recorder.



**ALNOR THERMO-ANEMOMETER** Here's a compact, direct-reading instrument that fills a long-felt need—the accurate measurement of low air velocities. With the Alnor Thermo-Anemometer you can accurately read velocities as low as 5 f.p.m. It can be used between 20°F. and 150°F. without impairing its accuracy. Fine craftsmanship, high-quality materials, exact calibration, and exhaustive tests combine to assure you accurate operation on a wide variety of applications.

**ALNOR ELECTRONIC TEMPERATURE CONTROLLER** . . . is a simplified form of controller designed to indicate and regulate automatically the heat of any industrial heating device. There are no moving mechanical parts to wear or cause trouble. Control sensitivity is such that pointer movement of 0.3% will activate the power relay. Available with a wide variety of thermocouples and in scale range from 0-500 to 0-3000°F.

**ALNOR DEW POINT INDICATOR** . . . for simple, rapid dew point reading of any gas. Indication takes place in an enclosed observation chamber under accurately controlled conditions. Dew or fog suspended in air—not on mirrored surface—makes it easy for two or more observers to get same accurate results. The Alnor Dewpointer is a complete, self-contained unit—no external coolant or other apparatus is required. Available for dew points from —80° F. to room temperature.

**ALNOR TYPE 2300 SURFACE PYROMETER** . . . sets a new high in precision measurement of low surface temperatures. Special design, from Alnico magnet to the finest, quick reacting thermocouple, assures unfailing accuracy . . . speed and dependability. This is a self-contained, sturdy unit—easily carried and used anywhere on a wide variety of applications. Direct reading, six-inch mirrored scale is easily read . . . quickly understood. The instrument is available in 5 Fahrenheit scale ranges with a span as small as only 150°.

# for precise measurement of temperature, air velocity and dew point!

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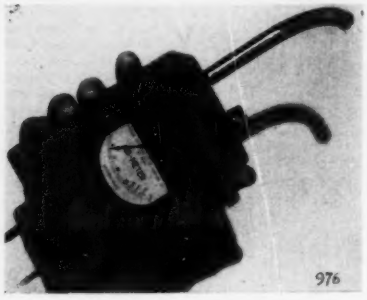
Sampling is implemented by a continuously-operating motor-driven pump which forces air sample through drier and then through analyzer where any carbon monoxide present is oxidized, and percentage registered on recording potentiometer.—*Mine Safety Appliances Co., Thomas and Meade Sts., Pittsburgh 8, Pa.*

**Mention No. 407 when filling out card.**

## Temperature-compensated Air-flow Meter

New "Model G Air-Meter" provides direct readings of air velocities from 5 to 6,000 feet per min. with an expanded scale in low-velocity ranges. Built-in compensation prevents momentary error in velocity reading when probe is subjected to sudden changes of temperature. Accessories available include a carrying case with battery-operated power pack for use when 110-v. a-c. power is not available.—*Hastings Instrument Co., Inc., Hampton, Va.*




**Menton No. 408 when filling out card.**

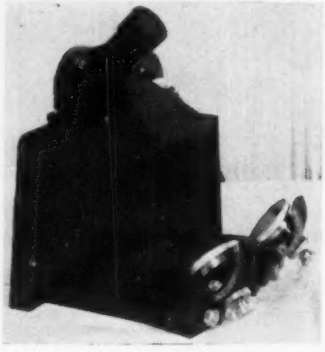
## Automatic Colorimeter

New automatic colorimeter is designed to measure color of cotton samples. Both yellowness and reflectance are measured. Photo-electric measurements are converted to color in special circuit using "Electronik" amplifier instead of galvanometer and reversible motors instead of human hands to standardize instrument and obtain color settings.—*Henry A. Gardner Lab. Inc., 4723 Elm St., Bethesda 14, Md.*

**Mention No. 409 when filling out card.**

## Illuminator and Viewer for Colorimeter

New illuminator simulates hand action of a human color matcher in orienting samples relative to source and angle of viewing. Illuminator may be combined with photo-electric measuring system to obtain quantitative values of reflected light intensities.—*Instrument Development Labs., 163 Highland Ave., Needham Heights 94, Mass.*



**Mention No. 411 when filling out card.**

## Tank-gaging Telemeter

New remote-reading tank-gaging system uses "Electronik" self-balancing indicator with a 6.3-v. d-c. circuit which employs four small-size lead wires for each tank to be gaged. System is adaptable to any of maker's standard automatic tank gages for both low and high-pressure storage tanks.—*Shand and Jurs Co., Berkeley, Calif.*

**Mention No. 412 when filling out card.**

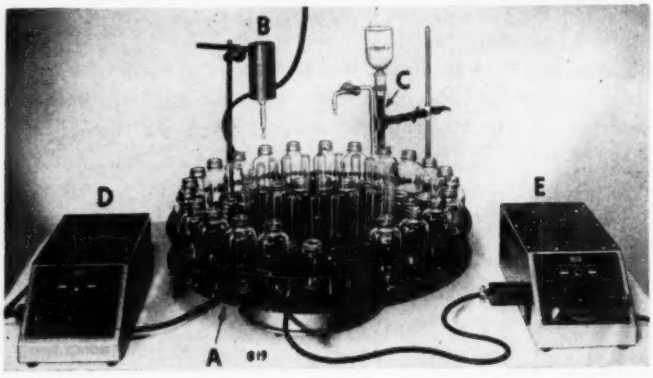
## Oscillograph Galvanometers

New "No's. 8001, 8002, 8003, 8004" ink-writing galvanometers have sensitivities from 3.5 to 40 volts per cm., resonant frequencies from 15 to 120 cps., resistances of around 1400 ohms, driving impedances of 250 ohms, frequency responses from 0 to 350 cps., and a single-jewel pivot construction. Units are designed for multiple operation up to 10 channels in a total width of 12 in.—*Edin Electronics Co., 207 Main St., Worchester 8, Mass.*

**Mention No. 413 when filling out card.**

## Liquid Fraction Dispenser and Collector

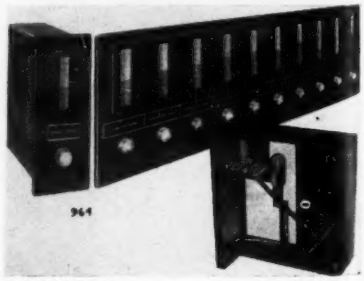
New dispenser and collector automatically delivers any volume from 0.5 to 50 cc. with impulses from 1 to 200 seconds (timer D) and collects fractions in up to 96 containers. Collection is actuated by timer E, giving intervals of 1, 5, 15, and 30 minutes, or 1, 2, and 4 hours.—*Microchemical Specialties Co., 1834 University Ave., Berkeley 3, Calif.*




**Mention No. 410 when filling out card.**

## Level Indicators

New "Model 240" level indicators operate from any 3-to-15 psi. pneumatic transmitter or direct from valve-loading pressures. Indicators may be mounted in groups up to eight units. Auxiliary switches and lights are available to provide high-low alarm. Units

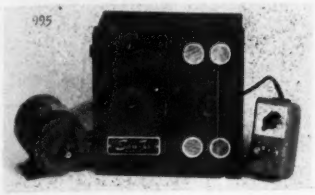


may be readily pulled from panel for inspection. Indication of level is given by a solid-red band rising on a translucent screen, graduated as required. Connections required are for signal-air pressure, and 115 v. for illumination.—*Panalarm Products Div., Panellit, Inc.*, 7218 *N. Clark St., Chicago* 26, *Ill.*

**Mention No. 414 when filling out card.**

## Motor-speed Control System

New thyratron-operated motor-speed control will handle shunt-wound 115-v. d-c. motors of from one-thousandth to one-tenth hp. over a speed range of

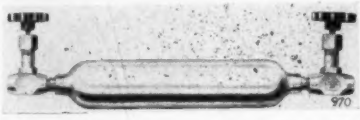


better than 50 to 1 with essentially constant speed vs. torque regulation. Similar model will handle 220-volt motors up to one-sixth hp. Feedback in control circuit is said to provide excellent regulation.—*Servo-Tek Products Co., 4 Godwin Ave., Paterson, N.J.*

**Mention No. 415 when filling out card.**

## Pressure-sample Containers

New Hoke stainless-steel pressure sample containers, for either production run or laboratory sampling, are available in two standard service



pressure ranges of 400 psi. and 1800 psi.; are ICC approved; may be obtained for either single or double valving; may be made, on special order, of other metals, ferrous or non-ferrous. —*Hoke, Inc., Englewood, N. J.*

**Mention No. 416 when filling out card.**

## Ion-exchange-bed Indicator

New "Monobed" indicator which changes color when ion-exchange bed is exhausted is a special dyed mixture of Amberlite resins. Blue in its regenerated state, bed becomes yellowish-brown when exhausted.—*Resinous Products Div., Rohm & Haas Co., Philadelphia, Pa.*

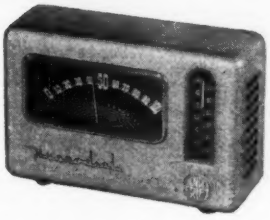
**Mention No. 417 when filling out card.**

## Strain Indicator

New "Type L" is an improved model of maker's portable battery-powered strain indicator for use with "SR-4" bonded resistance-wire strain gages. Total range is 20,000 microinches per inch. Balancing range is plus or minus 30,000 microinches.


FOR PRECISE READINGS ON RELATIVE HUMIDITY and TEMPERATURE ... RELY ON BENDIX FRIEZ

Accurate information on humidity and temperature is essential in laboratory and scientific work. Be sure of these facts with Bendix-Friez precision instruments built to the most exacting standards by the foremost manufacturers of weather instrumentation.



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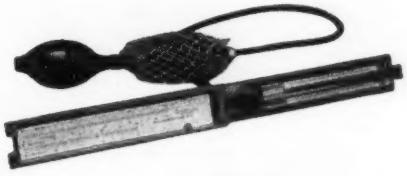
Hygrodial

**Precision Humidity and Temperature Indicator, Model 185**

Hair-operated and calibrated to professional standards of accuracy by the maker of the world's finest weather instruments. Handsome, modern case—4" high, 5½" wide, 1⅜" deep —desk or wall mounting. A genuine precision indicator reasonably priced.



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**Hand Aspirated Psychrometer, Model HA/2**

Pocket size, a new standard of convenience in measuring relative humidity. Accurate readings obtainable without special skill. Psychrometric readings can be taken at any point desired however inaccessible.

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3" x 5" charts, 10 or 30 hour records. Modern design . . . handy for small space and difficult locations . . . built to meet unusual conditions.

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No matter how much you know about soldering, there's always a trick that will make it easier. This little 20-page pocket guide is crammed full of such time-and-trouble savers.

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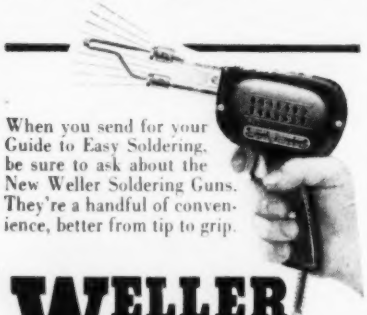

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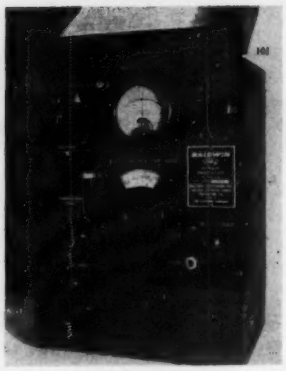


Oscilloscope connector jack is provided for applications in rephasing problems. —*Baldwin Locomotive Works, Philadelphia 42, Pa.*

**Mention No. 418 when filling out card.**

## Flow-rate Indicators

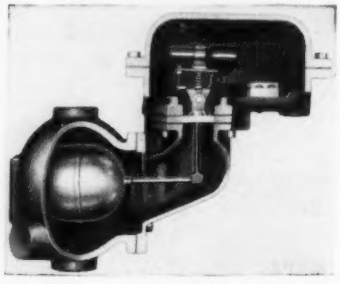
New "Bantam" type flow-rate indicators are available for flow range from 0.05 to 0.7 liters oxygen per minute and for from 10 to 100 cc.

carbon-dioxide per minute. Instruments may be used with air or non-corrosive gases and may be mounted on either pipe-line or auxiliary equipment.—*Hoke Inc., Englewood, N. J.*

**Mention No. 419 when filling out card.**

## Liquid-level Controller

New "No. 65" explosion-proof float-operated electric liquid-level controller has been Underwriters tested and approved for the following hazardous conditions: Class 1, Group C, ethyl-

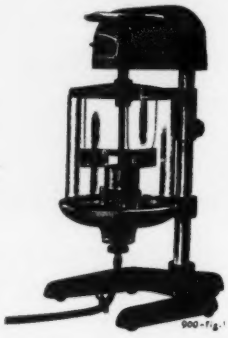


ether vapors, ethylene, or cyclopropane; Class 1, Group D, gasoline, petroleum, naptha, benzine, butane, propane, alcohols, benzol, laquer solvent vapors, or natural gas. Maximum body pressure is 40 lb. Mercury switch can be set to make or break on high or low level.—*McDonnell & Miller, Inc., Wrigley Bldg., Chicago 11, Ill.*

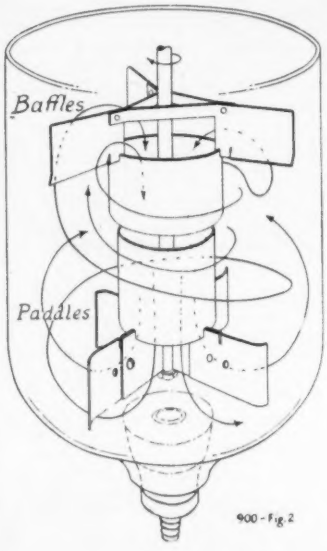
**Mention No. 420 when filling out card.**

## Laboratory and Small-production Mixer

New "Fisher-Goldman Mixer" is a small (3.5-gal. jar) manufactured model of custom-built industrial installations of Goldman mixers, utilizing the same combination of continuously-



rotating paddles and freely-suspended self-adjusting baffles with cylindrical extension. Paddles are adjustable for liquids of different viscosities. New




mixer cuts down mixing times as much as tenfold; intermingles liquid with liquid, liquid with solid, liquid with gas. Over-all height 22 in.; motor is 0.16 hp, either 115- or 230-volt 50-60-cycle. —*Fisher Scientific Co., 711 Forbes St., Pittsburgh 19, Penna.*

**Mention No. 421 when filling out card.**

## Vibration-fatigue Tester

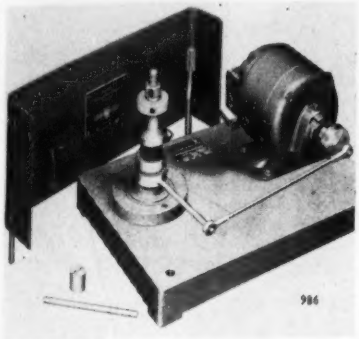
New "Model 100-HA-T" vibration-fatigue testing machine provides stepless acceleration from 10 to 100 cps. A 2-hp. d-c. motor operates from a thyratron control. Vibration frequencies are measured with a tachometer.

Components up to 100 lb. may be tested on 15 by 18 in. table which has a stroke adjustable from 0 to 0.125 in. Accelerations up to 10G are produced at full load with higher values for lighter loads.—*All American Tool & Mfg. Co.*, 1014 *W. Fullerton Ave., Chicago* 14, *Ill.*

**Mention No. 422 when filling out card.**

## Bearing-grease Tester

New "Fafnir" oscillating grease tester evaluates lubricating quality of greases by oscillating test bearings containing grease through an angle of



12 degrees at a rate of 3450 reversals per min. under a thrust of 550 lb. Bearings are weighed before and after a 50 hour run. Loss of weight indicates suitability of lubricant.—*Precision Scientific Co.*, 3737 *N. Cortland, Chicago* 47, *Ill.*

**Mention No. 423 when filling out card.**

## Variable Transformer-ratio Transducers

New "Types 1A400 and 1B400" 400-cps. variable-voltage-type mechanoelectrical pickups have secondary-to-primary voltage ratios continuously adjustable through rotation of a shaft. First type requires a booster amplifier.

# STABILINE VOLTAGE REGULATORS

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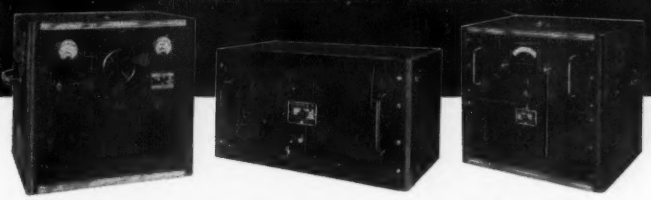
**THE SUPERIOR ELECTRIC CO.**



The Superior Electric Company packs into its voltage control equipment a wealth of research, design and production experience. Each unit is guaranteed to deliver — over normal periods of operation and life-expectancy — all the performance characteristics stated in Superior Electric advertising.

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Every STABILINE Automatic Voltage Regulator shipped from The Superior Electric Company has been inspected and tested to the most rigid mechanical and electrical specifications. It is your assurance that they will perform as advertised.

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**THE VARICELL *(above left)***

The latest Superior Electric development in voltage control equipment. Delivers DC voltage, variable from 0 to 30 volts, from an AC source. Output is stabilized — held to set values regardless of line variations. Output is regulated — unit automatically compensates for load fluctuations. Operates from any 95-135 volt, 60 cycle, single phase AC line. Stabilization and regulation are ±0.25% for output settings between 6 and 30 volts. R.M.S. ripple voltage does not exceed ±0.1 volts.

**STABILINE TYPE IE *(above center)***

Completely electronic and instantaneous in operation. No moving parts. Maintains output voltage to within ±0.1 volts of nominal for line voltage variations; to within ±0.15 volts for any load current change — or for any load power factor change from 0.5 lagging to 0.9 leading. Waveform distortion *never* exceeds 3%. Available in a wide range of capacities.

**STABILINE TYPE EM *(above right)***

Maintains constant voltage on heavily loaded lines. Features zero waveform distortion; complete insensitivity to magnitude and power factor of load; no effect on power factor; no critical adjustments; high efficiency; adjustable output voltage. Available for a wide range of applications in 115, 208, 230, 440 volt, single and three phase ratings; capacities to 100 KVA.

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The Superior Electric Company welcomes inquiries regarding any of its voltage control equipment. Your questions will receive prompt and complete answers. We're always ready to consult with you on voltage regulation problems — at no obligation to you.

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POWERSTAT VARIABLE TRANSFORMERS • VOLTBOX A-C POWER SUPPLIES • STABILINE VOLTAGE REGULATORS

Century MODEL 406

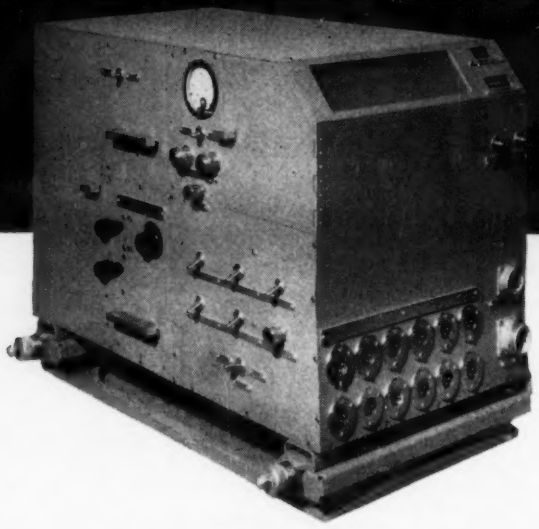
RECORDING OSCILLOGRAPH

FOR

VIBRATION – TEMPERATURE

STRESS – STRAIN ANALYSIS

where any or all of the above information is an important factor.



FEATURES

1. 12–50 individual channel recording.
2. Continuous recording up to 200' without jamming
3. Instantaneous changes of recording speeds up to 50" per second with automatic adjustment of lamp intensity.
4. Timing System — Discharge lamp controlled by temperature compensated tuning fork providing sharp .01 second with heavier .1 second timing lines. Conversion to .1 second lines only, by switching.
5. Independent optical system provides constant view of traces with optimum light intensity at all times.
6. Recording lamp under constant surveillance of external condition indicator lamps.
7. Galvanometers — with optional range of frequencies and sensitivities.
8. Electrical — Available for operation from option of 12 or 24 volts D.C., or 110 volts A.C.

OPTIONAL FEATURES

1. Trace identification by means of light interruption.
2. Trace scanning for observation of steady state phenomena.
3. Remote control unit.
4. Automatic record numbering system.
5. Automatic record length control.
6. Visual paper footage indicator.

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Philadelphia 7, Pa.

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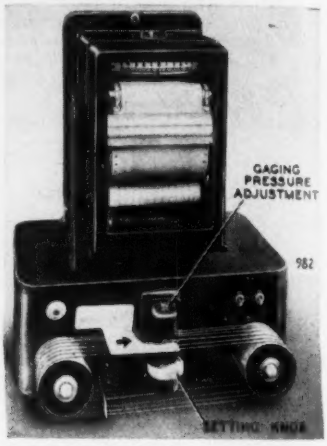
149 Broadway, New York


All circuits are isolated with self-contained terminal blocks. Units are designed for computers, but other industrial applications are apparent.—*Arma Corp., 254 36th St., Brooklyn 32, N. Y.*

**Mention No. 424 when filling out card.**

## Continuous Thickness Gage

New "Micrograph" thickness gage is an automatic comparator with standard full-scale graduation of plus or minus 0.0005 in. with each division representing 0.00002 in. With a 2-in. sample installed in instrument, an auto-

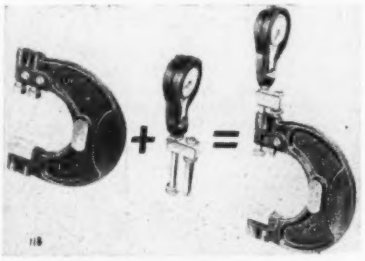



matic indexing and gaging system takes a reading every 0.25 in. which is recorded on a chart. Chart record then offers an accurate production-control graph of thickness variations across width. Instrument is designed for such material as cellophane, vinyl plastic, or thin papers.—*Pratt & Whitney, Division of Niles-Bement-Pond Co., West Hartford 1, Conn.*

**Mention No. 425 when filling out card.**

## Snap-gage Converter

New "Dializer" snap-gage converter converts ordinary AGD snap gages to dial instruments. Unit is inserted in place of two gaging pins of American Gage Design adjustable-limit snap gages. Thus a limit gage can be

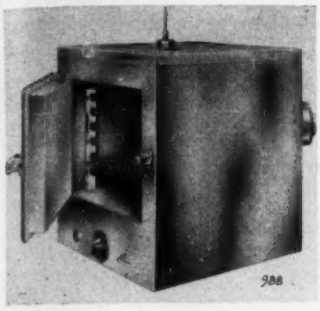


changed to a dial gage giving quantitative readings at a cost stated to be far below that of a new dial snap gage. Instruments reading in either 0.0001 or 0.001 in. can be furnished. Gaging-pin surface is either flash-chrome plate on hardened steel or tungsten carbide. —*Standard Gage Co., Inc., Poughkeepsie, N. Y.*

**Mention No. 426 when filling out card.**

## Laboratory Oven

New "Economy" forced-draft laboratory oven is made of welded double-stainless walls with glass wool insulation. Working chamber is 13 by 12 by 12

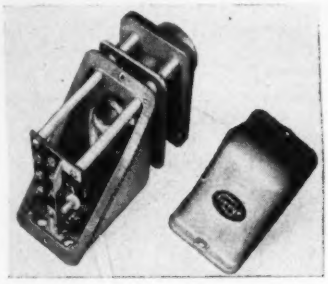


in., and power consumed is 1200 watts at 115 v. 60 cps. Oven is thermostatically controlled to within 1 degree C. from 35 to 200 C.—*The Electric Hotpack Co., Inc., 5029 Cottman Ave., Philadelphia 35, Pa.*

**Mention No. 427 when filling out card.**

## Flame-failure Alarm

New "Fireye System FF-1" flame-failure alarm and control will lock out start-up system of oil burner 5 sec. after power has been applied in event

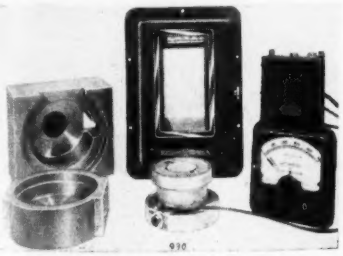


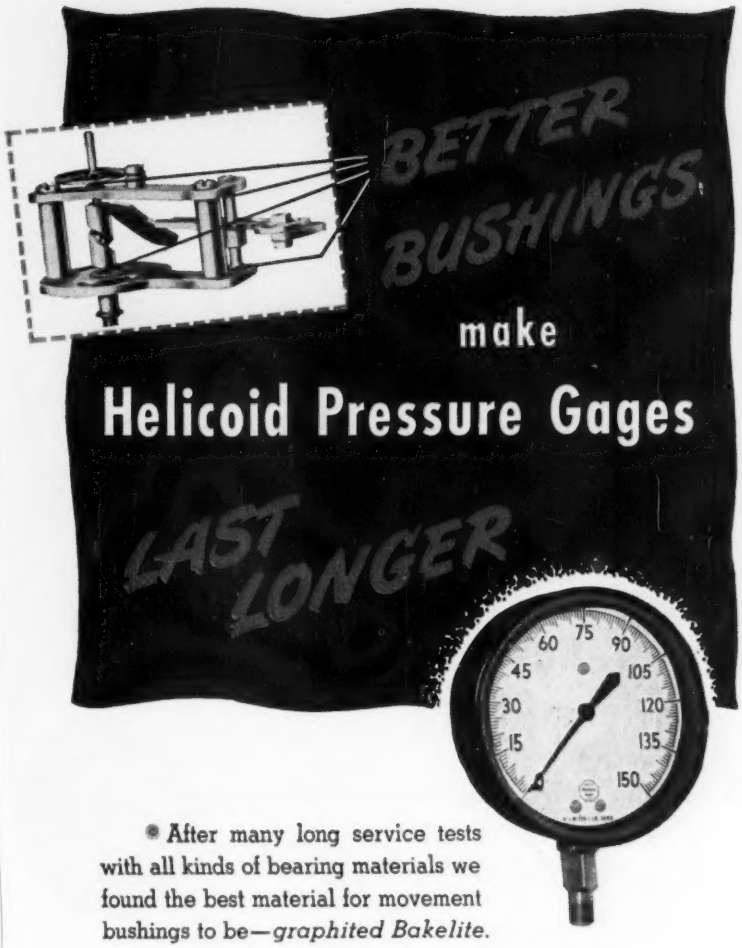
flame has not occurred. Also, if flame fails during operating cycle, lock-out will occur within 2 to 4 seconds. Unit will operate 1 hp. motor, 125 va. pilot, and 250 va. ignition.—*Combustion Control Corp., 77 Broadway, Cambridge 42, Mass.*

**Mention No. 428 when filling out card.**

## Pressure-block Gages

New "Electrolimit" pressure-block gages are designed to measure rolling pressures on continuous strip mills. Blocks are mounted between bearing and top screw or bottom housing, and measurement of pressure is obtained through a testing-ring compression in-

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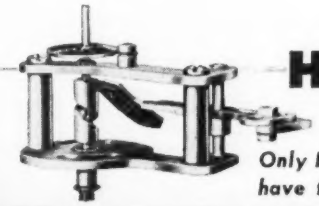
Helicoid movements with graphited Bakelite bushings have less static and kinetic friction. They are now standard in all Helicoid gages—at no extra cost.



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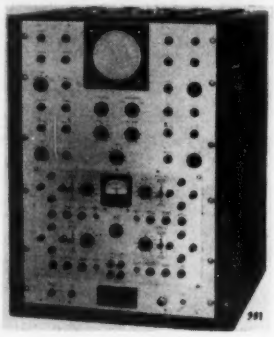
*2911 Spring Grove Avenue, Cincinnati 25, Ohio.*

dication which may be transmitted to a recorder. Temperature compensator is provided. Gages are available in capacities from 5,000 to 3 million lb.—*Pratt & Whitney, Div. of Niles-Bement-Pond Co., W. Hartford 1, Conn.*

**Mention No. 429 when filling out card.**

## Vibration-strain Analyzer

New "Model H-42" vibration-strain analyzer is designed to work with "Baldwin SR-4" resistance strain gages of 60 to 1000 ohms. Indicator is dual-gun cathode-ray tube with electrostatic

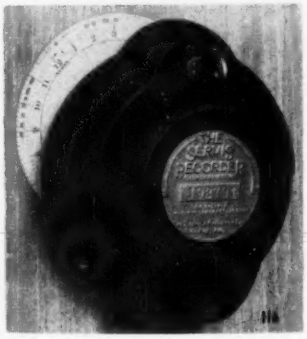


focus and deflection. Frequency range is 0-50,000 cps. plus or minus 0.5 db. Deflection sensitivity is better than 0.002 v. per in. Sweep range is from 2 cps. to 50 kc., continuous, or 0.5 sec to 20 microseconds triggered.—*Electronic Tube Corp., 1200 E. Mermaid Lane, Chestnut Hill, Philadelphia 18, Pa.*

**Mention No. 430 when filling out card.**

## Time Recorder

Several new models of "Servis Recorder," for busy time and idle time of motor trucks and machinery feature a device which marks on chart exactly



when recorder was unlocked. Mark appears as a round dot on face of chart and is also embossed on back.—*The Service Recorder Co., 1375 Euclid Ave., Cleveland 15, Ohio*

**Mention No. 431 when filling out card.**

## Paper Tensiometer

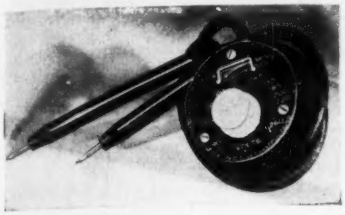
New paper tensiometer consists of a small steel roller, mounted on ball bearings, which rides on top of moving paper, mounted so that a slight dimple is depressed in sheet. Changes in paper tension shift roller's position a friction of an inch. Roller is fixed at

end of an arm, which bends as roller rises or falls. Bending of arm is measured by a strain gage.—*Special Products Div., General Electric Co., Schenectady, N. Y.*

**Mention No. 432 when filling out card.**

## Miniature Voltmeter

New "Model 410A Mini-Volt" voltmeter is accurate to within 2 v. at 110 v., a.c. Glow-lamp indicator is guaran-

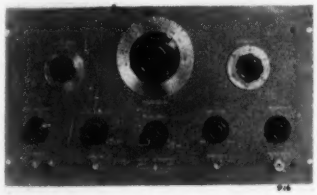


teed for 25,000 hours operation minimum. 12 in. flexible test leads are tipped with heavily insulated test prods.—*Industrial Devices, Inc., Edgewater, N. J.*

**Mention No. 433 when filling out card.**

## General-purpose Pulse Generator

New "Model 212A" general-purpose pulse generator for testing "fast" circuits, as well as making everyday checks, has unusually fast pulse rise and decay time (0.02 microseconds), high power (50 watts) pulse, and continuously-variable pulse length (0.07 microseconds to 10 microseconds). A

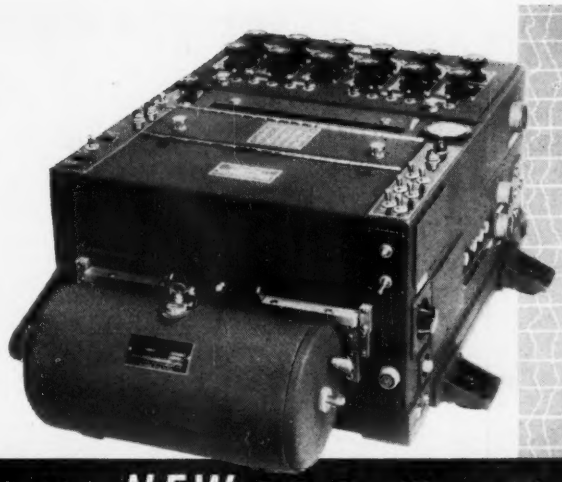


low internal impedance (50 ohms or less) insures a pulse shape virtually independent of load, also makes it possible to deliver accurate pulses at some distance from instrument, if transmission lines are properly terminated. Repetition rate (frequency) is continuously variable from 50 to 5,000 pulses per second, can be controlled internally or from an external synchronizing source. Continuously-variable synchronization pulses are available either in advance or following main pulse. An amplifier-attenuator system with low source impedance makes possible either positive or negative pulses with continuously variable amplitude. —*Hewlett-Packard Co., Palo Alto, Calif.*

**Mention No. 434 when filling out card.**

## TV Alignment Marker

New "Dual Mega-Marker Sr." TV alignment instrument has been designed to provide crystal-controlled markers for sound and picture carriers on each of twelve TV channels. These

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**FULL-RESILIENT MOUNTING FOR MOTOR AND TRANSMISSION isolates all possible vibration and makes possible the use of modern super-sensitive galvanometers**

**NEW GALVANOMETER STAGE accommodates *all* Hathaway galvanometer for recording milliamperes, microamperes, or watts**

**NEW RECORD-LENGTH CONTROL AND NUMBERING SYSTEM designed for long, trouble-free service under all kinds of ambient conditions**

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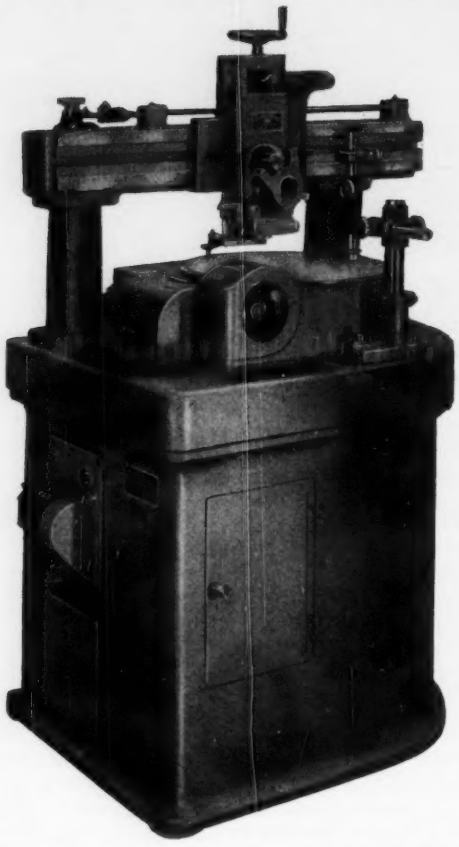

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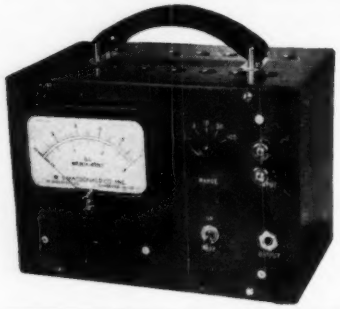

THIS instrument is designed to replace high-sensitivity galvanometers in many applications. Due to its ruggedness, freedom from burnout, and relative insensitivity to shock, it is an ideal instrument for use in balancing resistance bridges, measuring crystal rectifier output, photo-cell, strain-gage, thermocouple, and lead-sulphide cell currents, etc. The instrument may also be used as a DC pre-amplifier for recorders. When used in this manner, current amplification of 1,000 is available.

SPECIFICATIONS:

Sensitivity •
**1 microampere** full scale
**50 microvolts** full scale

Ranges •
1, 3, 10, 30, 100 microamperes

Permissible overload –
**½ ampere**
Accuracy – ±3% full scale
Time constant – about 6 seconds
Power supply – 110 – 125 V, 60 C.P.S.
Dimensions – 7" x 8" x 9½"

PRICE — $250.00 F.O.B. CAMBRIDGE, MASS.

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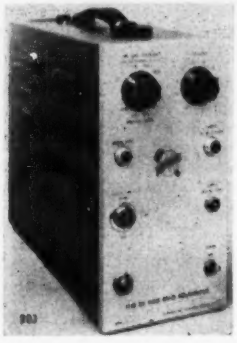
two markers appear simultaneously for channel selected by a front-panel switch, at a panel coaxial connector. A second coaxial panel connector supplies 4.5 Mc signal. Outputs are continuously variable. Picture-carrier markers are accurate to 0.01 percent and separation between sound and picture carriers is 4.5 Mc plus and minus 500 cps. Output level at RF is approximately 100,000 microvolts.—*Kay Electric Co., Pine Brook, N. J.*

**Mention No. 435 when filling out card.**

### Wide-band Pre-amplifier

New "Type 121" wide-band pre-amplifier has been designed primarily to increase sensitivity of maker's cathode-ray oscilloscopes. Max. gain of 100, plus combined attenuator and gain con-

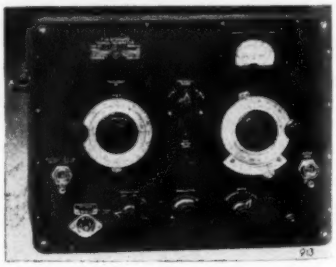


trols, permit a sensitivity range from 2.5 mv. per cm. to 25 v. per cm. without use of attenuators. Band width is in excess of 10 Mc. A front-panel power-supply socket provides d-c. plate and heater voltages so that a cathode-follower probe or a special pre-amplifier stage mounted directly on signal source may be used.—*Tektronix Inc., 712 S.E. Hawthorne Blvd., Portland 14, Ore.*

**Mention No. 436 when filling out card.**

### FM Signal Generator

New "Type 1022-A" FM standard signal generator has carrier-frequency range of 88 to 108 Mc. and i-f. range of 10 to 11.5 Mc. Modulation system is

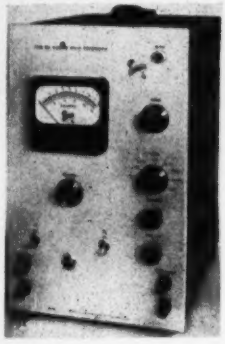


flat from 20 cps. to 15 kc. with internal-modulating frequencies of 60 and 400 cps. Deviation range is 0 to 200 kc. with less than 5 percent incidental AM. Output is continuously variable from below 0.1 microvolt to above 1 volt, with impedance of 50 ohms.—*General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

**Mention No. 437 when filling out card.**

## Square-wave Generator

New "Type 105" square-wave generator is continuously variable in frequency from 25 cps. to 1 Mc. Risetime of approximately 0.02 microseconds is

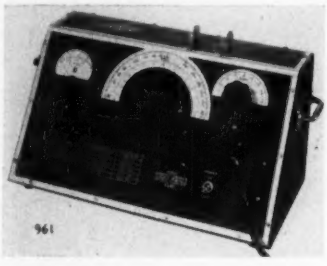


maintained at all frequencies without overshoot. Generator has max. current capability of 160 m.a. to output load. When used with 93-ohm output cable, as furnished, approximately 15 v. is available.—*Tektronix Inc., 712 S. E. Hawthorne Blvd., Portland 14, Ore.*

**Mention No. 438 when filling out card.**

## Coil Checker

New "Model 301A" combines a VTVM, a calibrated variable capacitor and an amplifier tube into a single instrument. When coupled with any



r-f. oscillator, it measures inductance, distributed capacitance and "Q" of any inductor as well as capacitance of mica capacitors.—*Clough Brengle Co., 6014 Broadway, Chicago 40, Illinois.*

**Mention No. 439 when filling out card.**

## Time Marker for CROs

New "Labmarker" is essentially a wave-shaping device used to produce time marks in cathode-ray oscillography. It converts a sinoidal input voltage (maximum amplitude 30 volts rms.) into a series of sharp unidirectional pulses, which may be displayed

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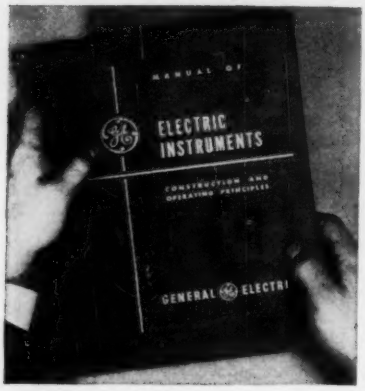


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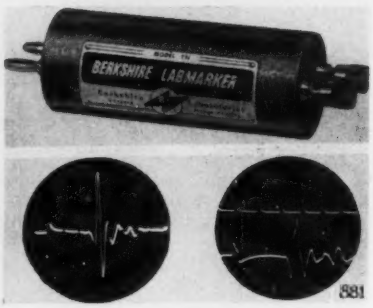
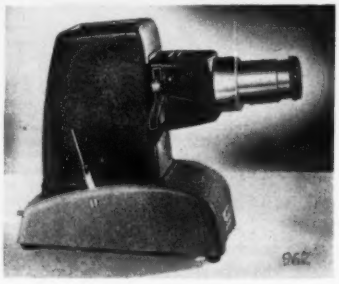



directly on tube face by connecting marker's output to vertical input. Timing marks consisting of short breaks in trace are obtained by connecting marker's output to "Z" input terminals. Both timing methods are shown (unretouched photographs showing spike potentials in giant internuncial fibers of the cockroach, with 1000-cycle time marks). Unit may be plugged into terminals of an a-f. oscillator. No other power source is required.—*Berkshire Laboratories, P. O. Box 701, Concord, Mass.*

**Mention No. 440 when filling out card.**

## Colorslide Projector

New "Performer 150 Delineascope" 2 x 2 colorslide projector is said to offer a number of important features found on maker's higher-priced "MC



300 Delineascope": high light output on screen from 150-watt lamp; remains cool enough for comfortable handling; high fidelity of color reproduction and evenness of illumination over the entire picture area.—*Instrument Div., Am. Optical Co., Buffalo, N. Y.*

**Mention No. 441 when filling out card.**

## R-f. Waveform Monitor for TV Transmitters

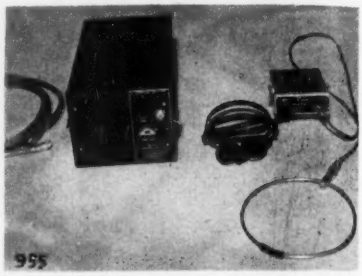
New r-f. "Type 5034-A" waveform monitor is designed for use in TV broadcast installations to monitor unrectified r-f. signal at r-f. transmission

line. C-r. tube displays r-f. carrier voltage on a linear time base at either field- or line-frequency. Further provision is made for measuring relative amplitude of various portions of envelope within FCC accuracy limits. Instrument can read any modulation level directly as "percentage of peak signal."—*Allen B. Du Mont Labs., Clifton, N.J.*

**Mention No. 442 when filling out card.**

## Ignition-harness Tester

New "RT-1" ignition harness leakage tester for aircraft, airport maintenance, etc., locates leakage in aircraft harness which interferes with

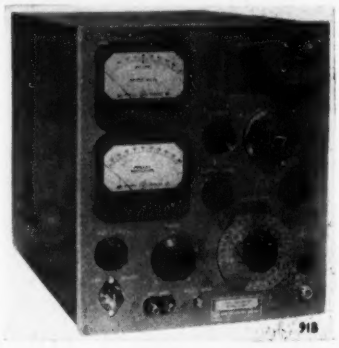


VHF radio reception. Operation is on 150 Mc. Equipment includes receiver, transmitter, loop, cables and plugs. Tester permits checking each individual spark plug harness without operation of the engine.—*Gertsh Products Co., 11,896 Mississippi Ave., Los Angeles 64, Calif.*

**Mention No. 443 when filling out card.**

## VHF Signal Generator

New "Model 608A" signal generator for range 10 to 500 Mc. has calibrated output from 0.1 microvolt to 1.0 v. reading directly in volts and



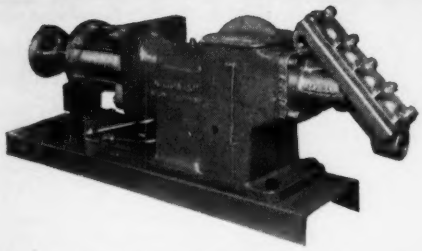
dbm. Drum-type dial has effective length of 90 in. Output is CW, AM, or pulsed down to microseconds. M.O.P.A. circuits are enclosed in cast-aluminum shield.—*Hewlett-Packard Co., 395 Page Mill Rd., Palo Alto, Calif.*

**Mention No. 444 when filling out card.**

## Oscilloscope

New "Type 250-AH" cathode-ray oscilloscope employs a "Type 5RP-A" high-voltage cathode-ray tube. Accelerating potential for tube, supplied by an external high-voltage power supply,

MILTON Roy PUMPS



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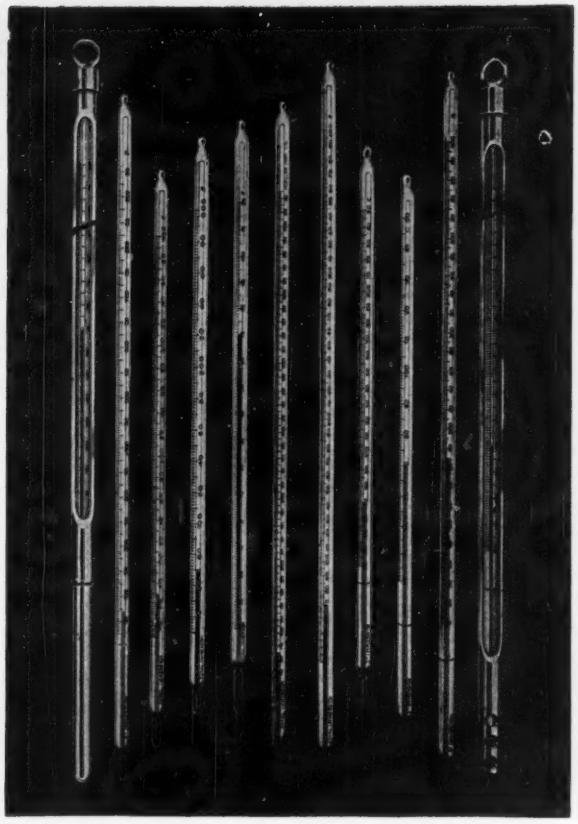

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**SPECIFICATIONS**

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**Presentation:** Recurrent solutions for all variables, via one or more oscilloscopes (not supplied), plotted against time or against one another.
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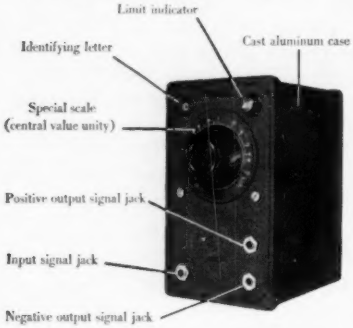


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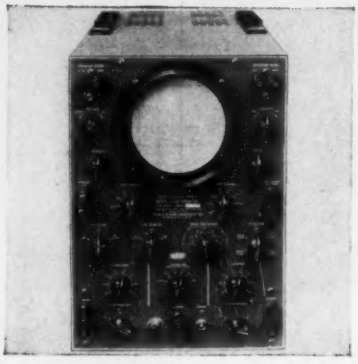
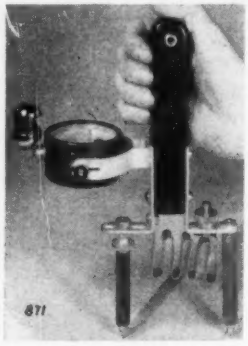


is 13,500 volts. High potential makes possible observation and photographing of high-speed signals recurring either at random or at slow, recurrent intervals. "Type 250-A," a low-voltage version also available, employs a "Type 5CP-A" tube operated at an accelerating potential of 3,000 volts.—*Instrument Div., Allen B. Du Mont Labs., Inc., Clifton, N. J.*

**Mention No. 445 when filling out card.**

## Battery-cell Tester

New "No. 17" battery-cell tester instantly shows condition of a 6-volt battery. Double-scale meter is calibrated 3-0-3. Prods are adjustable and will fit terminals on any battery. Col-




ored dial has scale reading: dead, discharged and charged. A special light illuminates dial in dark places and goes out when cell is dead; dims when cell is low—*General Scientific Equipment Co., 2700 W. Huntington St., Philadelphia 32, Pa.*

**Mention No. 446 when filling out card.**

## D-c.-a-c. Chopper

New "Mini-chopper" vibrator for both d.c. and a.c. weighs 1.3 oz.; has a normal life of over 1,000 hours; fits a standard seven-prong miniature tube socket. With a rated input of 6.3 v., it will modulate from 60 to 600 cps. Unit is hermetically sealed, and is un-

affected by temperatures from minus 55 C. to plus 120 C.—*Servomechanisms Inc., Old Country and Glen Cove Rds., Mineola, N. Y.*

**Mention No. 447 when filling out card.**

## Direct-coupled Amplifier

New "No. 8100" direct-coupled amplifier has a voltage amplification of 10,000 with a max. output of 70 v. Frequency response from d.c. to 10,000 cps. is within 10 percent. Time constant is infinite; square-wave response is flat. Input impedance is 2 megohms and output 250 ohms. Input may range from 0.1 mv. to 10 v. There is less than 1 v. drift per hour at full gain after warm-up with 5-v. line variation. Attenuator is stepped for factors from 1 to 1000.—*Edin Electronics Co., 207 Main St., Worchester 8, Mass.*

**Mention No. 448 when filling out card.**

## Biological-research Amplifier

New "No. 8121" special amplifier is similar to maker's direct-coupled amplifier described above but has a time constant of 1 second, an exponential response to a square wave at high gain, an input impedance of 1 megohm, and a max. input of 1000 v. At low gain, characteristics are slightly different.—*Edin Electronics Co., 207 Main St., Worchester 8, Mass.*

**Mention No. 449 when filling out card.**

## Amplitude Modulator

New "Type 1023-A" amplitude modulator, will provide up to 80 percent modulation at 60 cps. for a signal generator. External frequencies be-

tween 20 cps. and 15 kc. can be used. Input and output impedances are 50 ohms. R-f. range is 10 to 150 Mc. with a gain of 0.1, and 10.1 to 11.3 Mc. with a gain of 10.—*General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

**Mention No. 450 when filling out card.**

## VHF Bridge

New "Model 803 A" impedance measuring bridge for region of 50 to 500 Mc. permits readings from 2 to 2000 ohms. Range can be extended to 5 to 1000 Mc. Impedance is determined by sampling magnetic and electric fields of a transmission line. Phase is meas-

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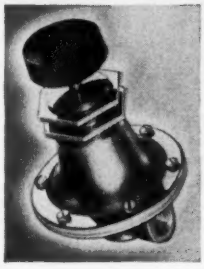

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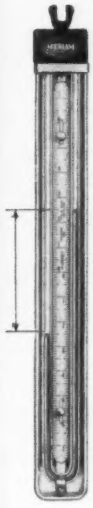
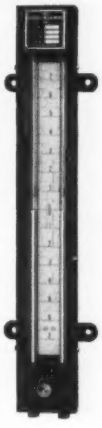


### U-TYPE MANOMETERS



**The Clean-Out Manometer** (at left) for line pressures up to 100 lbs. per sq. in. A wing nut permits the Manometer body and tube to be disconnected from the head — the tube cleaned with a brush furnished or tube replaced, and the instrument reassembled without disconnecting the head section from the piping. Send for Bulletin No. 1.

**The Model A-995 WM Manometer** for line pressures up to 400 lbs. per sq. in. These instruments are built with heavy walled annealed straight Pyrex tubes, gland packed top and bottom in steel end blocks and clamped to the body at fixed intervals to prevent distortion. Catalog Sheet A-995 WM gives complete details.

### WELL-TYPE MANOMETER

Model A-275 WM (at left) is a direct reading type for line pressures up to 150 lbs. per sq. in. Standard construction; ranges — from 6" to 24". Wall mounted type shown; also available in flush mounting. Ask for Catalog Sheet A-275 WM.

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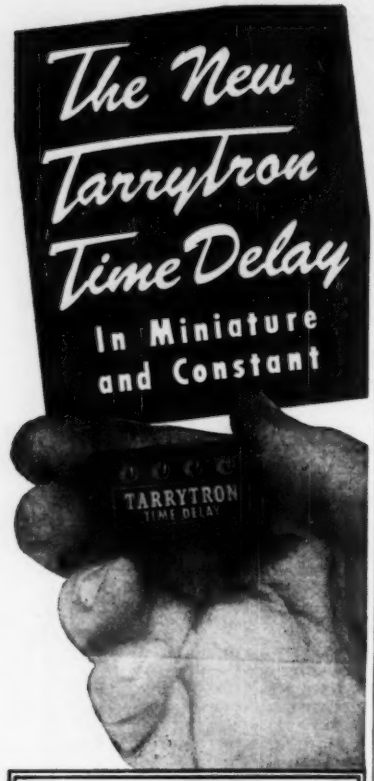


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ured by determining point of cancellation of samples along a second transmission line.—*Hewlett-Packard Co., 395 Page Mill Rd., Palo Alto, Calif.*

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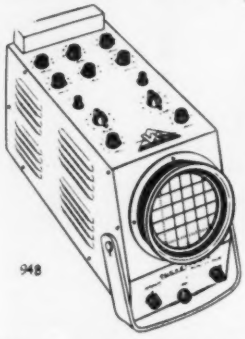
## Portable Oscilloscope

New "Model S-14-A" oscilloscope is 12 by 5.75 by 7 in. dim. and weighs 12.5 lb. It has identical vertical and horizontal channels with 10 mv. per in. sensitivity, a response within 2 db. from

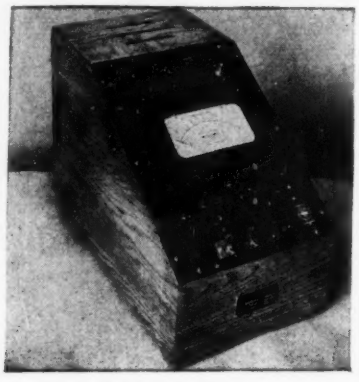


0 to 200 kc., non frequency-discriminating attenuators, internal trace-amplitude calibration, linear repetitive or trigger sweeps with positive or negative synchronism from 0.5 cps. to 50 kc., trace expansion, and a filter screen.—*Waterman Products Co., Philadelphia, Pa.*

**Mention No. 452 when filling out card.**

## Megohm Meter

New "Model L-4A and Model L-6A" megohm meters feature an internal circuit assuring that applied voltage is specified value as long as resistance of piece under test is within range of



meter. First model contains an internal 500-volt measuring source, as well as a 200-volt source. Second features a continuously-variable measuring source from 100 to 600 volts d.c.—*Industrial Instruments, Inc., 17 Pollack Ave., Jersey City 5, N. J.*

**Mention No. 453 when filling out card.**

## VHF Detector

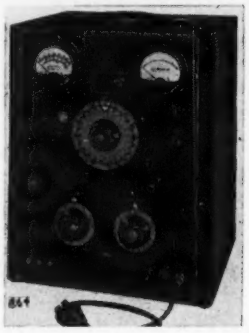
New "Model 417 A" detector for range 10 to 500 Mc. is essentially a super-regenerative AM receiver with direct-reading frequency control. In-

strument is suitable for general laboratory work including approximate frequency checks, and noise and interference measurements.—*Hewlett-Packard Co., 395 Page Mill Rd., Palo Alto, Calif.*

**Mention No. 454 when filling out card.**

## FM Signal Generator

New "Type 202-D" frequency-modulated signal generator covers range 175 to 250 Mc. and is provided with three continuously-adjustable deviation



ranges of 0 to 24- 80- and 240 kc. Internal audio oscillator provides eight fixed frequencies between 50 cps., and 15 kc. Deviation sensitivity is within 0.5 db from d.c. to 200 kc. Amplitude modulation is essentially flat from 30 cps. to over 100 kc.—*Boonton Radio Corp., Boonton, N. J.*

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## Electrostatic Generators

New electrostatic generators of 6 and 20 kv. output are powered by a spring motor which runs for 20 min. on one winding. Motor speed is controlled by a governor which results in

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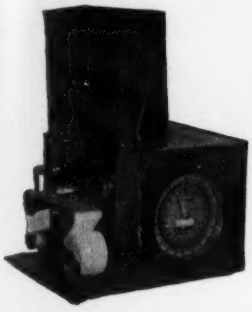

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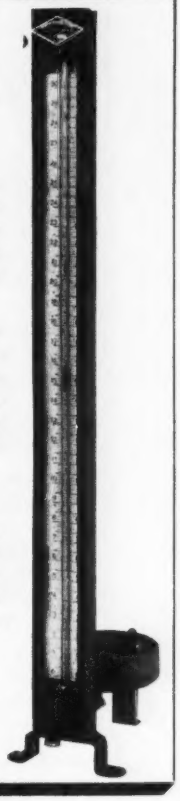

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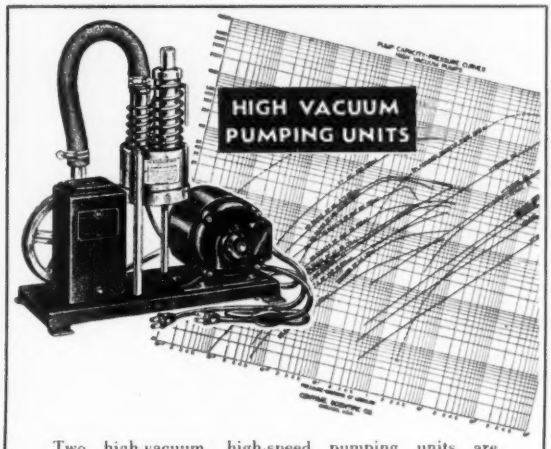


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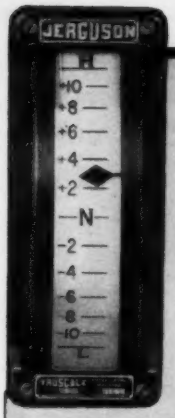


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constant current output. Constant voltage is attained with a corona-discharge regulating tube. Units were designed as portable voltage supplies for infrared-sighting equipment. Weight is 10 lb.—*Chatham Electronics Corp., Newark, N. J.*

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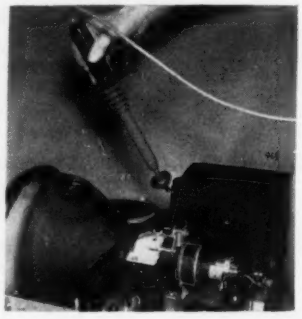
## High-voltage Probes

New "Types WG-289 and WG-290" high-voltage probes provide an input resistance of at least 1000 megohms. First type, for use with electronic voltmeters, has a microphone-type con-

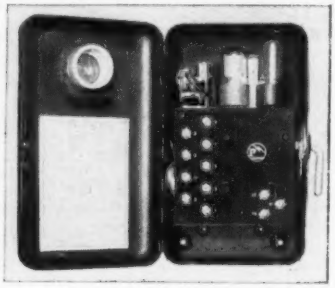


nector, and second a telephone type. Insulation provides over 8.5 in. surface leakage path, and is designed to minimize corona. Probes will be especially useful in TV servicing.—*RCA Victor Div., Radio Corp. of America, Camden, N. J.*

**Mention No. 457 when filling out card.**

## Photoelectric Switch

New "Series 20" photoelectric switch operates over a distance of 10 to 20 feet depending on light source and will con-

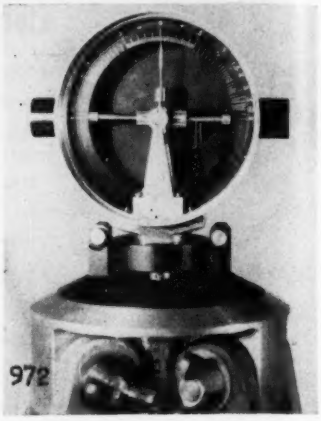


trol up to 0.5 hp., non-inductive. Relay will operate in 0.05 sec. Contacts are d-p.d-t.—*Photoswitch Inc., 77 Broadway, Cambridge 42, Mass.*

**Mention No. 458 when filling out card.**

## Universal Magnetometer

New "Lee" universal magnetometer is capable of both horizontal and vertical work. A built-in coil, similar to Helmholtz type, is used for calibration or for operation as a null device. Tem-




perature compensation is provided. Instrument is self levelling and direct reading. Sensitivity is adjustable, and can be corrected for latitude. Tripod is similar to conventional transit mounting.—*Geophysical Instrument Co., Arlington, Va.*

**Mention No. 459 when filling out card.**

## TV-test Autotransformer

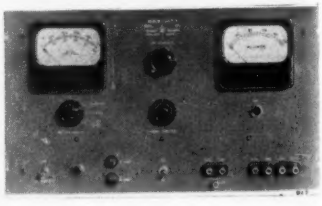
New "WP-25A Isotap" autotransformer is designed for servicing television receivers. Primary is adjustable in 5-volt steps from 105 to 130 v., and

secondaries provide 275 va. isolated for servicing of transformerless receivers and 500 va. for larger sets which are equipped with power transformers.—*RCA Victor Div., Radio Corporation of America, Camden, N. J.*

**Mention No. 460 when filling out card.**

## Power Supply

New "Model 712A" power supply provides a variable plate and bias supply voltage, as well as a-c. voltages for general laboratory use, is similar in design to maker's "Model 710A" but



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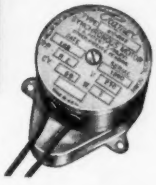

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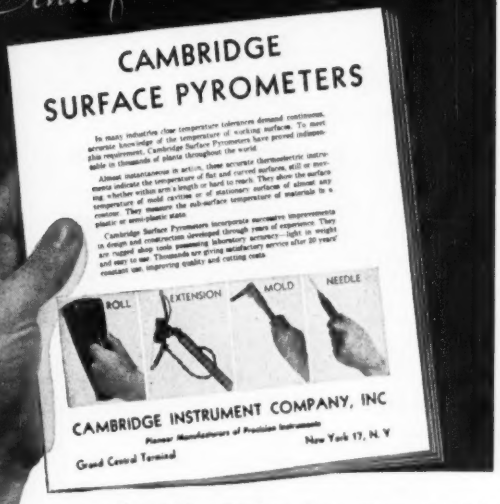


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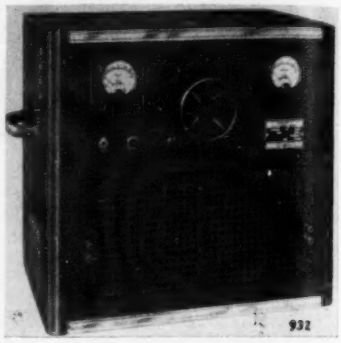
## Regulated D-c. Supply

New "Varicell" provides a stabilized and regulated source of variable d-c. voltage from a-c. power lines. It operates from a 95 to 135-v., 60-cps., single-phase a-c. line; delivers a d-c. output variable from 0 to 30 v. Output current at any voltage setting is 15 amp. Stabilization and regulation are given as 0.25 percent for an output setting between 6 and 30 v. Ripple voltage does not exceed 0.1 rms.—*The Superior Electric Co., Hannon Ave., Bristol, Conn.*



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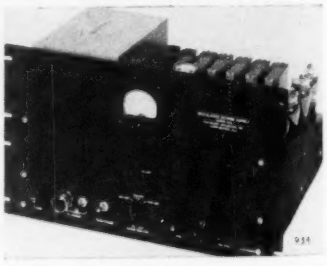
## Regulated D-c. Power Supply

New "Model 107" power supply has output of 100 to 400 v., up to 250 ma. d.c., with less than 1 percent variation for line-voltage variations from 100 to 135. Hum level is within 5 mv.—*Electronic Associates Inc., Long Branch, N. J.*



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## R-f. Power Supply

New "Model 99" variable high-voltage r-f. power supply delivers 1 to 40 kv. with negative or positive polarity. Unit will also supply 6.3 v. filament current and low-voltage d.c. for accessory equipment. Rectifier filaments are energized from r-f. transformer to assure constant heater current with variable-output voltage. No electrolytic

capacitors are used. Components are housed in all-aluminum cabinet.—*Inductograph Products, 236 W. 55th St., New York 19, N. Y.*

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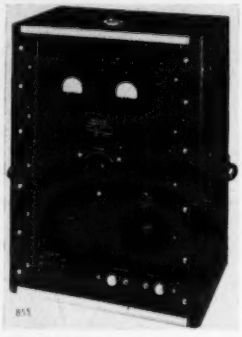
## Regulated D-c. Power Supplies

New "Models 1110 and 1110-A" power supplies with outputs of 175-1000 volts at 0.50 amps. and 175-1500 volts at 0.33 amps. respectively in con-

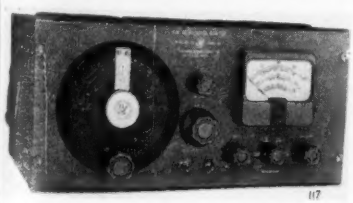


tinuously-adjustable ranges have output variation of less than 5 volts for line variations between 105 and 125 volts. Ripple is less than 20 mv. Front panel fits a standard relay rack. Weight 185 lbs. For 115-v. 50-60 cps. operation.—*Furst Electronics, 12 S. Jefferson St., Chicago 6, Ill.*

**Mention No. 465 when filling out card.**

## FM Modulation Monitor

New "Model MD-25" modulation monitor for measuring frequency departure of FM transmitters under modulation is designed to continuously cover 30 to 50 Mc., 72 to 76 Mc., and 152 to 162 Mc. in four bands. Either upward or downward swing can be measured up to 20 kc. with an accuracy of better than one kc. on an easily read 4 in. indicator. Sensitivity of instrument makes possible measurements with less than 1 mv. present on



antenna terminals. Unit is constructed with an 8.75 in. standard-rack panel and housed in a steel cabinet. Panel is finished in black leatherette with black wrinkle on cabinet.—*Browning Labs. Inc., Winchester, Mass.*

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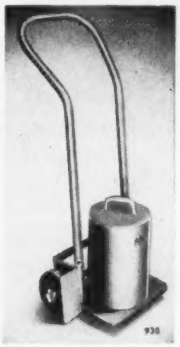
## Radioactivity Shield

New "Mark 3, Model 35" safety shield for radioactive material permits convenient transfer on rubber-rimmed wheeled carrier. Iron shield is 9 in.



dia. by 12 in. high with wall thickness of 3 in. Storage chamber is 3 in. dia. and 6 in. deep.—*Radiation Counter Labs., Inc., 1844 W. 21st St., Chicago 8, Ill.*

**Mention No. 467 when filling out card.**

## Radioactivity Indicator

New "Model 2610A" beta-gamma portable count-rate meter is housed in a water-tight case. Interior is tropicalized to eliminate effects of humidity. Probe is also water-tight and contains a plug-in type Geiger tube to facilitate

servicing. Indicator is calibrated in both milliroentgens per hour and in counts per minute. Instrument is supplied complete with an attached radioactive source for checking calibration, batteries and crystal earphones.—*Nuclear Instrument and Chemical Corp., 223 W. Erie St., Chicago, Ill.*

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## Radioactive Sample Carrier

New "Mark 8, Model 50" sample carrier for radioactive material has a handle 5 ft. long with a rubber grip.

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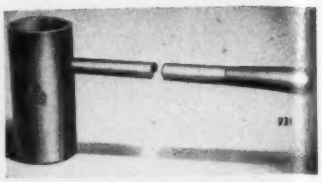

Exposure is reduced by a factor of 100. Container has dia. of 3 in. and is 6 in. long.—*Radiation Counter Labs., Inc., 1844 W. 21st St., Chicago 8, Ill.*

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## Prospectors' Geiger Counter

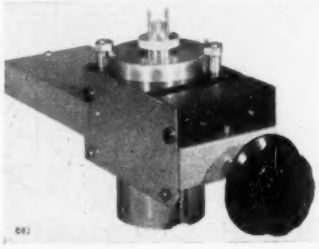
New "Model 106" portable geiger counter will detect beta particles as low as 160 kev. as well as gamma, cosmic and x-rays. It employs a 900-v. Geiger tube, with a 30 mg. per sq. cm.

thin-window section, which has a life in excess of 100 million counts. A stainless-steel probe is optional. Size, approx. 3.5 by 4 by 6.5 in.; weight, approx. 3.5 lbs.; ranges, 20, 2 and 0.2 milliroentgens per hour; sensitivity, beta and gamma.—*Precision Radiation Instruments, Inc., 5478 Wilshire Blvd., Los Angeles 36, Calif.*

**Mention No. 470 when filling out card.**

## Radioactivity Proportional Counters

New "Models GCC-1 and GCC-2" counter chambers for use with Gooch crucibles have a background of about 5 counts per minute, and when used



with maker's "Model PC-1" counters will work up to 500,000 counts per minute with a resolution loss of 1 percent per 100,000. Gas used is 9 parts argon to 1 of methane.—*Nuclear Measurements Corp., 3339 Central Ave., Indianapolis 5, Ind.*

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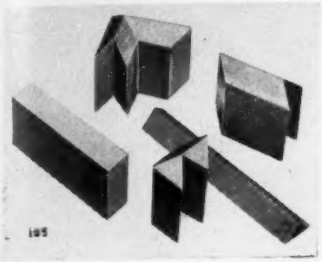
## Radioactivity Shielding

New "Model 3039" interlocking lead brick sections are so designed that a complete dense wall may be obtained. Standard 4 by 4 by 2 in. wall bricks

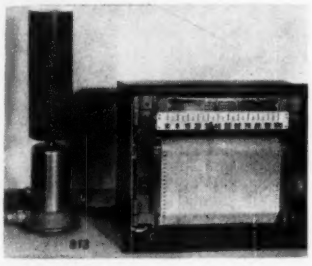


can be assembled with two types of corner bricks, and a triangular filler is available to eliminate low-density area at bottom of structure.—*Nuclear Instrument and Chemical Corp., 233 W. Erie St., Chicago 10, Ill.*

**Mention No. 472 when filling out card.**

## Electrometer for Radioactivity

New recording electrometer uses vibrating capacitor to convert d-c. potentials to a.c. for subsequent amplification. Result is an instrument which will measure 100 millionths of a microampere at an input resistance of 0.1 mega-megohms. Ranges supplied are

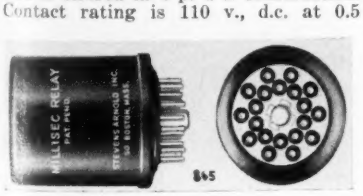


–1 to 10, –10 to 100, and –100 to 1000 mv. Max. zero drift is 0.3 mv. per day. System accuracy is 1 percent of scale reading. Background noise is about 5 microvolts. Input capacitance is 30 micromicrofarads. Available speeds of response are 12 or 4.5 seconds full-scale. Power consumption is 65 watts. —*Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Philadelphia, Pa.*

**Mention No. 473 when filling out card.**

## High-speed D-c. Relay

New "Type 172 Millisec" relay has operating time as short as a third of a millisecond, is hermetically sealed, and is offered in 6-p. d-t. construction. Contact rating is 110 v., d.c. at 0.5

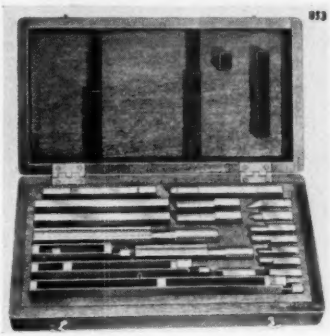



amp., and coils are 1400 ohms at 0.9 henry or 150 ohms at 0.14 henry for d.c. only. Socket is 20-pin octal.—*Stevens-Arnold Inc., 22 Elkins St., S. Boston 27, Mass.*

**Mention No. 474 when filling out card.**

## Accessories for Gage Blocks

New "No. J-19" accessory set designed for use with all makes of precision gage blocks includes jaws, straight edges, and three adjustable holders in various sizes, as well as a center point and

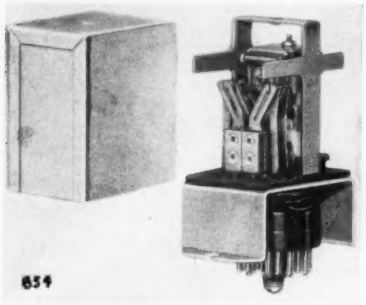


scriber. Jaws are furnished in six sizes of solid and I-beam design. Included are two straight edges (four-blade type) which are said to be accurate to within four microinches per inch of length. Center point and scriber, when used with adjustable holder, establish locations within 0.0001 in. Accessories are also available individually.—*Jansson Gage Co., 19208 Glendale Ave., Detroit 23, Mich.*

**Mention No. 475 when filling out card.**

## Relay Enclosure

New dust-tight plug-in enclosure for maker's "Type J" relay has a steel cover and neoprene gasket fitted to



relay terminals. Installation is facilitated by use of a standard radio-type plug.—*C. P. Clare & Co., 4719 W. Sunnyside Ave., Chicago 30, Ill.*

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## High-pressure Reducing Valve

New "Type E" high-pressure reducing valve is recommended for reducing pressure of water, oil, and compressed air in a single stage from up to 6000 psi. to within 20 percent of initial pressure. For lower reduced pressures,


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reduction is made in two stages, through this valve and then through a valve for handling pressures up to 300 psi. Body is forged steel. Internal metal parts are of chromium-plated stainless. Plastic-cup piston washers are made to suit high-pressure service. Hand-wheel at top permits adjustments to be quickly made.—*The Atlas Valve Co., 282 South St., Newark 2, N. J.*

**Mention No. 477 when filling out card.**

## Variable Transformer

New design of "Powerstat" variable transformers, "Type 116 and 216" retains standard-mounting dimensions and ratings, but features diecast-aluminum terminal box on cord-plug models, terminal board of phenolic plastic, and a new fusing arrangement where a twist-lock holder on side of terminal box gives easy access and simple replacement.—*The Superior Electric Co., Hannon Ave., Bristol, Conn.*

**Mention No. 478 when filling out card.**

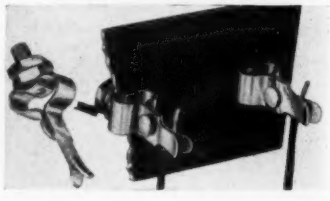
## Attenuators

New "Model 20 and Model 21" attenuators, housed in rugged cast metal cases, cover frequency range of 0 to 500 Mc. First model has constant input and output impedance of 53.5 ohms; second has 70 ohms. A fixed-insertion loss of 10 db and switchable-insertion loss in 1-db steps to a total of 41 db are provided. Dimensions are 2 by 8.25 by 1.5 in.—*Kay Electric Co., Pine Brook, N. J.*

**Mention No. 479 when filling out card.**

## Test Clip

New test clip has simplified design. Leads are slipped in or out of clamp-type jaws. Spring action holds wire

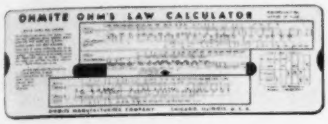


firmly until operator pulls out lead. Tension of spring action is adjusted by tightening hex nut that mounts clip to panel.—*Grayhill, 4524 W. Madison St., Chicago 24, Ill.*

**Mention No. 480 when filling out card.**

## Ohm's Law Slide Rule

New Ohm's Law calculator, featuring new scales, provides a standard slide rule as well as a quick, one-setting means of solving parallel-re-

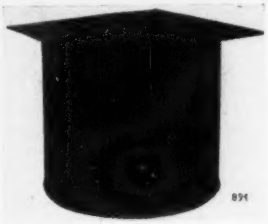


sistance problems. Rule will multiply, divide, and find square roots, and is made of varnished cardboard, in pocket size, 9 by 3 in.—*Ohmite Mfg. Co., 4937 Flournoy St., Chicago, Ill.*

**Mention No. 481 when filling out card.**

## Frequency-sensitive Relays

New "900 Series" 400-cps. frequency-sensitive relay operates with a frequency differential of one-quarter percent. Pull-in and drop-out spread can

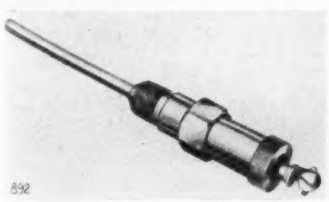


be set from 2 to 40 cps. Example setting: to pull in at 365 cps. within 0.5 cps. and drop out at 360 within 0.5. Relays are hermetically sealed. Multiple contacts may be used to either open or close a desired circuit. Design is such that failure of frequency-sensitive relay removes all loads.—*Varo Mfg. Co., Box 638, Garland, Texas.*

**Mention No. 482 when filling out card.**

## High-temperature Switch

New "Super High Temperature Thermal Switch" for use in jet engines, gas turbines, rocket motors and afterburner controls, ranges from 0 to

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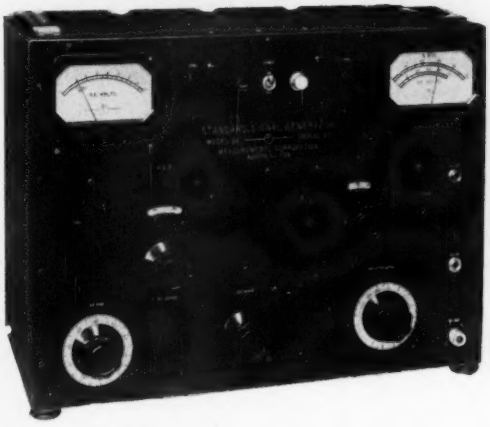

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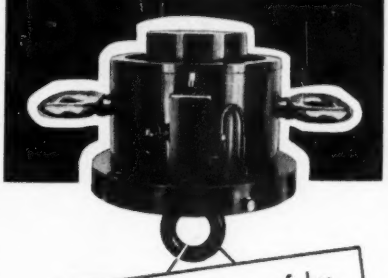

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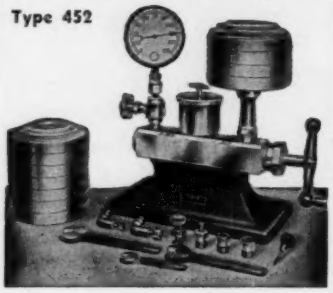

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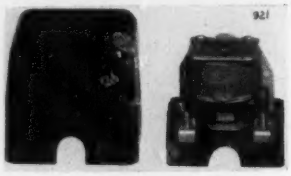
2000 F. normally open. Maintains temperature calibration for 100 hours at 1500 F. within 10 F. Flange or screw type mounting optional. Switch grounds on temperature rise. Probe 3 in. long; weight 5.5 oz.—*Control Products, Inc., 306 Sussex Street, Harrison, N. J.*

**Mention No. 483 when filling out card.**

## Motor-starting Relay

New "CR 1057—J" voltage-type relay, designed specifically for starting single-phase capacitor-start and capacitor-start capacitor-run motors, will pick



up at a predetermined voltage, after more than 500,000 operations, with change in calibration of less than 2 percent. Contact rating is 50 amp. at 115 v. and 30 amp. at 230 v.—*General Electric Co., Schenectady 5, N. Y.*

**Mention No. 484 when filling out card.**

## Precision Switch

New "Type SXX Unimax" snap-acting precision switch is rated at 15 amp., 250 v., a.c.; 20 amp., 125 v., a.c.; 0.75 hp.; 125, 250, 460 v. a.c. Force and

movement specifications are as follows: operating force, 9-13 oz.; release force, 4 oz. min.; movement differential, 0.005 travel, 0.005 in. min.—*Unimax Switch Div., W. L. Maxson Corp., 460 W. 34th St., New York 1, N. Y.*

**Mention No. 485 when filling out card.**

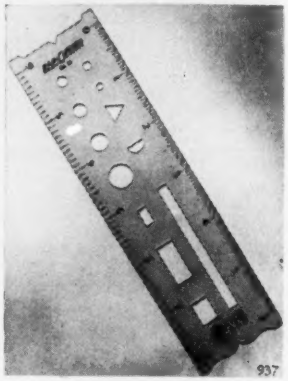
## Moistureproof Glass Electrodes

New series of moistureproof glass electrodes for maker's pH electrode assemblies of Pyrex-glass and enameled cast-iron types have electrode lead-wires permanently molded into plastic electrode head to assure high insulation and low electrical leakage. Thus, electrode maintains accuracy under high atmospheric humidity. Other claimed benefits: fast response (valuable on automatic-control applications); low resistance for accuracy at low temperature and for minimizing insulation problems; sodium error so low that the same electrode can be used for any range of acidity or alkalinity.—*Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia 44, Pa.*

**Mention No. 486 when filling out card.**

## Combination Scale and Template

New "No. 20 Sketch Scale" combines a Transparent pocket rule, scaled in



10ths and 16ths, with cut-outs for making field sketches, etc.—*Rapidesign, Inc., Box 592, Glendale, Calif.*

**Mention No. 487 when filling out card.**

## Audio Wave Filters and Reactors

New wave filters and reactors which weigh approx. 2 oz. have unusually

high inductance and Q values.—*Acme Electronics Div., Acme Metal Die, Inc., 212 E. 17th St., Los Angeles 15, Calif.*

**Mention No. 488 when filling out card.**

## Special-application Reactors and Transformers

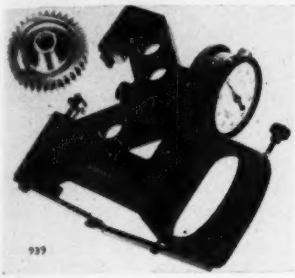
New designs and production of transformers and reactors are for specialized applications, including airborne pulse transformers, radar-type transformers, high-Q reactors, oscillator

blocking transformers, and others. Hypersil core material and Permafil impregnation are used. Die-made lead-covered lock-seam steel cases are stocked to facilitate production of cased units. Terminals of cased transformers and reactors are hermetically sealed with glass or ceramic-solder seal bushings.—*Sperry Products, Inc., Danbury, Conn.*

**Mention No. 489 when filling out card.**

## Spline Gages

New internal and external spline gages will check gears having odd or even number of teeth. Gages, which

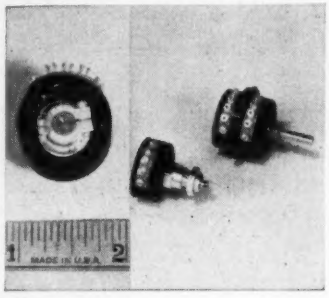


are self aligning, are designed as adaptations of maker's bore and snap gages.—*Nilsson Gage Co., Inc., 2A Lake St., Poughkeepsie, N. Y.*

**Mention No. 490 when filling out card.**

## Miniature VDRs

New miniature voltage-dividing resistors 0.875 in. dia. and 0.376 in. deep, are available in resistance ranges of 100 to 25,000 ohms. Accuracy of total

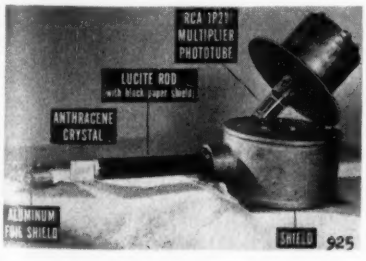


resistance may be specificed as close as 1.0 percent and linearity to 0.8 percent of total resistance as required. Units may be ganged together with adjusting clamp ring to permit individual phasing. — *Technology Instrument Corp., 1058 Main St., Waltham 54, Mass.*

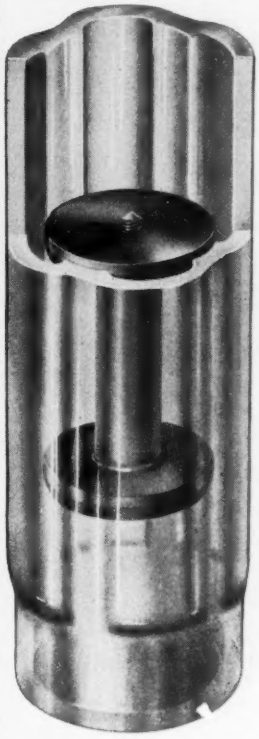
**Mention No. 491 when filling out card.**

## Multiplier Phototube

New model of maker's "1P21" multiplier phototube embodies further improvements. Equivalent noise input has been reduced to $5 \times 10^{-13}$ lumen at room temperature—a six-fold reduction in operational noise permitting a corresponding reduction in lower limit of measurable light intensities. Illustration shows application of new tube in atomic research with use of a light-







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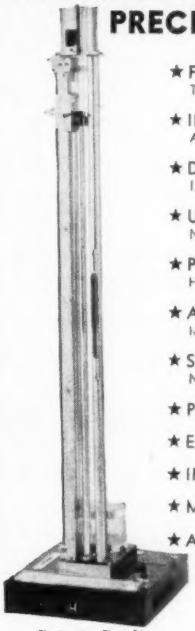

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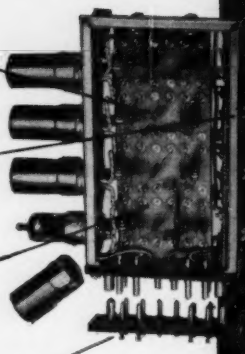

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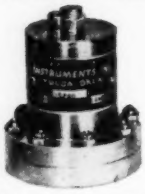

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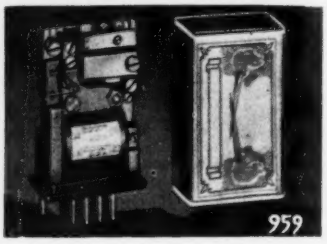
piping technique to measure radiation generated by a cyclotron. New tube is particularly useful where light is to be picked up from a small area. (For applications in which radiation is available from a relatively large area, maker's recently announced "5819" multiplier phototube is said to offer advantages.)—*RCA Tube Dep't., Radio Corp. of America, Harrison, N. J.*

**Mention No. 492 when filling out card.**

## Polarized Relays

New (to American instrumentation market) Carpenter Polarized Relays (made by Telephone Mfg. Co., Ltd.) are said to be capable of repeating, with high accuracy, feeble signal impulses

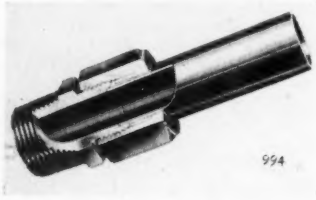



of varying time duration, and of maintaining this ability for long periods without attention. They are currently available in three sizes, "Type 5" (shown) is a matchbox-size relay weighing 4.8 oz., primarily developed for military and aircraft uses.—*C. P. Clare & Co., 4719 W. Sunnyside Ave., Chicago 30, Illinois.*

**Mention No. 493 when filling out card.**

## Flareless Tube Fitting

New flareless tube fitting permits installation without special tools; is available in all standard sizes up to and including 1 in. O.D. with special




sizes up to 2 in. Elbows, tees, crosses, etc., are machined from forgings; others from bar stock. Fittings meet J.I.C. Hydraulic Standards and Spec. AN-F-47.—*The Aircraft Fitting Co., 1400 E. 30 St., Cleveland 14, Ohio.*

**Mention No. 494 when filling out card.**

## Miniature Connector

New miniature 15-contact connector has over-all dimensions of 0.75 by 1.5 in.; is molded of mineral-filled dielectric. Female contacts are silver-plated beryllium; male contacts are silver-plated brass. Cables up to 0.561 in. can be accommodated. Seven and eighteen-contact connectors are also available. —*American Phenolic Corp., Chicago 0, Ill.*

**Mention No. 495 when filling out card.**

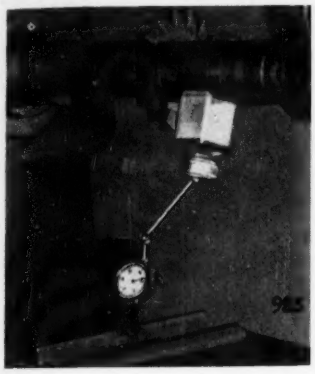
## Phosphorescent Screen

New phosphorescent screen consists of a metal plate coated with a special long-duration phosphor. Placed in a camera instead of film, it can be used to test synchronizers by observing image of a flash bulb on retentive screen. If bulb is not fully illuminated in image, synchronizer is not correctly adjusted.—*Flashback Sales*, 118 *Windsor St., Kearney, N. J.*

**Mention No. 496 when filling out card.**

## Magnet-base Holder for Indicators, etc.

New "Miti-mite" universal-joint holder uses an Alnico magnet, which exerts a 50-lb. pull, for attachment to



any iron or steel surface. Holder is useful for a variety of test instruments.—*Enco Mfg. Co.*, 4522-24 *W. Fullerton Ave., Chicago* 39, *Ill.*

**Mention No. 497 when filling out card.**

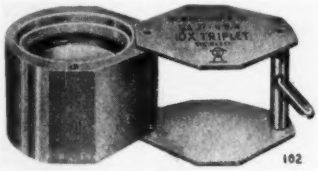
## High-voltage Connectors

New connectors, suitable for moderately high voltages as used in nuclear research or for high-altitude work, have an insert body molded from Melamine with machined silver-plated contacts. Connectors are keyed, and arranged so that ground wire is first to make and last to break. Six models are available as complete assemblies. A special six-conductor cable for use with new connectors is also available. —*Atomic Instrument Co.*, 160 *Charles St., Boston, Mass.*

**Mention No. 498 when filling out card.**

## Pocket Magnifier

New pocket magnifier uses 10-power triplet lens mounted in an aluminum



cell, and protected by a stainless frame. —*Stratex Instrument Co.*, 1861 *Hillhurst Ave., Los Angeles* 27, *Calif.*

**Mention No. 499 when filling out card.**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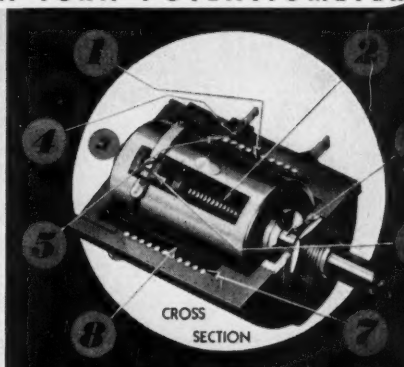


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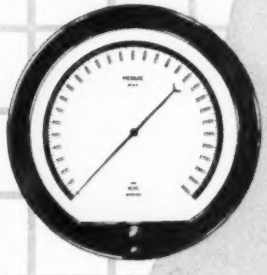

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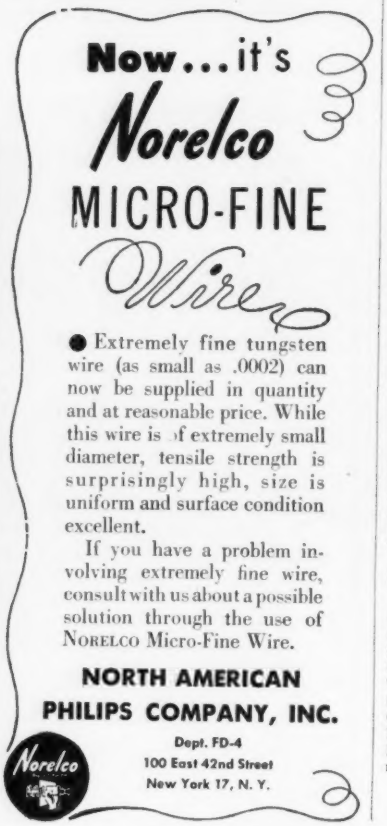
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**Education** *Continued from page 346*

mometer, Wheatstone Bridge, Resistance Thermometer Lead Wire Compensation, Maintenance and Testing of Resistance Thermometers.

11—Hour Examination.

12—Review of Elementary *Fluid Flow* Principles.

13—Orifice Construction and Installation, Pitot Tube.

14—Flow Meter Manometer, Recording Flow Meter Design.

15—Recording Flow Meter Integration, Planimeter Integration, Automatic Integration, Accuracy of Recording Flow Meters, Maintenance and Testing.

16—Area-Type Flow Meters. Rotameters, Anemometers, Electrical Air-Conductance Meters.

17—*Liquid-Level Measurement.* Visual Type, Float-Actuated Type, Recording Instruments, Electrical Contact, Manometer Type, Bourdon Tube Type, Diaphragm Type, Compensation for Mercury Suppression.

18—*Telemetering.* Electrical Telemetering Methods, Pneumatic Telemetering.

19—Hour Examination.

20—*Automatic Control Theory.* Theoretical Principles. Forms of Energy Controlled, Description of a Typical Automatically Controlled Process.

21—Analysis of Lags in an Automatically Controlled Process.

22—Thermometric Lag. Signal-Transferring Lag. Controller Lags.

23—Control Mechanisms. Available to Cope with Process and Response Lags.

24—Graphic Analysis of Process Characteristics Using Different Control Mechanisms.

25—General Discussion of Problem of Control, Mathematical Analysis of Process Characteristics.

26—Automatic Control Valve Characteristics.

27—Self-Operated Control Mechanisms. Servo Operated Control Mechanisms.

28—Air Operated Control Mechanisms.

29—Manual Reset Adjustment, Air Operated Control Mechanisms with Automatic Reset, Air-Operated Valve Positioners.

30—Electrically Operated Control Mechanisms.

31—*Miscellaneous Industrial Instruments.*

## TECHNICAL SOCIETIES

### Conference on Telemetering

A technical Conference on Telemetering, sponsored jointly by the AIEE Joint Subcommittee on Telemetering and the National Telemetering Forum, will be held May 24-26, 1950, at the Benjamin Franklin Hotel in Philadelphia, Pa.

This conference is to serve as a background for exchanging points of views and terminology of mobile radio and point-to-point telemetering systems. A full program of papers and inspection trips, correlated with the subject, is being planned.

### SESA

The Spring Meeting of the Society for Experimental Stress Analysis will be held at The Hotel Statler, Cleveland, Ohio, on May 25th, 26th, and 27th, 1950. Inquiries should be addressed to the Society for Experimental Stress Analysis, P. O. Box 168, Cambridge 39, Massachusetts.—W. A. MURRAY

### Society for Applied Spectroscopy

The May meeting of the Society for Applied Spectroscopy will be held on Tuesday, May 2. 6:00 p.m.: Informal Dinner, Tosca's, 118 Fulton St., New York. No reservation necessary. 8 p.m.: Regular Meeting, Socony-Vacuum Training Center, 63 Park Row, New York. Speaker, Dr. Harry S. Read, (Harry S. Read Co.). Subject, Theory and Demonstration of Emission Spectrograph Optics and the New Read Stigmatic Mounting. Technical Chairman, Richard Wiley (National Lead Co.).

—RODGER W. LOOFBOUROW, Merck & Co., Inc., Chemical Control Div., Rahway, N. J.

JOURNAL of the Instrument Society of America

I.S.A. National Office, 921 Ridge Ave., Pittsburgh 12, Penna.

Vol. 6 APRIL 1950 NO. 4

# New York Section Regional Conference

The New York Section, ISA, has again come through with flying colors in successfully conducting its third Regional Conference. The two day conference took place on January 27 and 28 at the Hotel Statler in New York City. Registration and attendance figures are as follows:

Registration on Friday—143, on Saturday—50, total—193. ISA members from the New York Section—63, from other Sections—36, Students—11, Non ISA members—93. Dinner Attendance was 125.

The program presented 7 technical papers on Temperature Measurement and Applications in Industrial Instrumentation.

The Friday Morning Technical Session under the chairmanship of R. J. S. Pigott, President ISA, had three papers: "Bimetallic Thermometers" by E. R. Kebbon, Weston Electrical Instrument Co.; "Temperature Measurement by Gas Flow Methods" by W. A. Wildhack, Missile Instrumentation Section, National Bureau of Standards; "Pneumatic Operated Temperature Controllers" by C. Owen Fairchild, Consulting Engineer.

There were three papers on Friday afternoon: "Measurement of High Gas Temperatures by Spectroscopic and Optical Methods" by Dr. F. B. Bundy, General Electric Company; "Steel Plant Temperature Measurement" by J. W. Percy, United States Steel Corp. Research Laboratory; "Electronic Self Balancers" by F. L. Maltby, The Bristol Company. Chairman of this session was Professor Carl F. Kayan, Columbia University.

A paper at the Dinner Session, "The Mosquito, Its Habits and Hobbies" by William Offenhauser, Jr., Consultant, was given. The Toastmaster was E. Ralph Manning, President New York Section, ISA.

A Saturday Morning Session, under the chairmanship of C. J. Zeller, Consolidated Edison Company of New York, had a paper "Fundamentals of Temperature Measurements" by Professor E. P. Lambe, Pratt Institute, Brooklyn.

Following the paper, four instrument companies, Automatic Temperature Control Co., The Bristol Company, C. J. Tagliabue Corp., and The Wheelco Instrument Co., cooperated in putting over a four-hour Instrument Maintenance Clinic which ran through Saturday afternoon. An open forum on "Temperature Instrument Maintenance" closed the program.

Conference Committeemen were Adolph K. Joecks, Chairman, Ralph R. Batcher, Norman J. Cherry, Charles E. Haggerty, H. R. Kalbfleisch, George Kauer, Jr., Franklin B. Leslie, John E. Warren and C. J. Zeller.

# Third Annual Regional Conference Dinner

Hotel Statler, New York City, Friday, January 27, 1950

**Seated at head table, left to right: Charles J. Zeller, Assistant Conference Chairman; Nelson Gildersleeve, Vice President, ISA; Richard Rimbach, Executive Secretary, ISA; E. Ralph Manning, President, New York Section, ISA; William Offenhauser, Jr., Guest Speaker; Adolph K. Joecks, Conference Chairman.**

# A New Recording Refractometer*

By O. E. BARSTOW†

## Introduction

SINCE refractive index varies with chemical composition this physical property has long been used in the laboratory to measure chemical concentrations.[1] Such measurements are generally made with so-called critical-angle refractometers of which there are three most common types, the Abbe[2], the Pulfrich[3] and the immersion[4] instruments. These instruments provide one of the simplest, most accurate and reliable physical means of analysis possessed by the testing laboratory.

Unfortunately, no instruments for automatically recording refractive index are available commercially. However, instruments for this purpose have been described in the literature. These fall into two general types, the spectrometer type[5] in which the sample is run through a hollow refracting prism and variations in the deviation of a transmitted light beam measured, and the reflection type[6] in which a beam of light is multiply reflected from a sample-glass interface and the intensity of the reflected beam measured.

The present paper describes a new type of recording refractometer.[7] This is an instrument whose optics are essentially those of a laboratory immersion refractometer but which is read automatically instead of visually.

## The Flowing Sample Visual Refractometer

The first step in making a critical angle refractometer automatic is to provide for a continuous flow of thermostated sample past the refractometer prism. A variety of styles of flowing sample visual refractometers were used during the war to show concentrations of styrene in ethyl benzene, butadiene in butene mixtures, and for other uses. One such instrument is available commercially.[8]

Fig. 1 shows diagrammatically the principle of one form of the instrument. The glass prism 1, objective lens 2 and eye piece 3 are standard parts from a Bausch and Lomb dipping refractometer. The prism, a cylindrical piece of glass with one end cut square and the other obliquely to the cylindrical axis is mounted in a cell 4 in a constant temperature bath 5 provided with the necessary stirrer, heater and thermostat (not shown). The sample flows into the apparatus at 6, through the heat exchange coil 7 to bring it substantially to the bath temperature, thence past the sloping surface of the prism and out at 8. Light from the sodium arc lamp 9 passes through window 10 to the sample-prism interface. Some of the light is refracted, passing through the prism, and is focused by the lens 2 to form the familiar light-dark field in the plane of the scale lens 11. This field magnified by the lens 12 and observed by the eye 13 has the appearance shown at 14, 15 and 16 where the light-dark dividing line moves downward across the field as the refractive index increases. By reading the position of the light-dark dividing line against a uniform arbitrary scale engraved on the scale lens and referring to a suitable table the operator can get the refractive index of the sample or its concentration. Since sodium light is used no Amici or compensating prism is required.

## Principle of the Recording Refractometer

To convert the flowing sample visual refractometer into a recording refractometer it is necessary to provide a means for locating and following the light-dark boundary automatically and positioning a pen accordingly. Fig. 2 shows diagrammatically the method used. The light source, bath, prism and objective lens are the same as for the flowing sample visual refractometer. However, the eye piece including the scale lens and eye lens has now been replaced by a narrow slit about 0.1 mm wide and a type 931-A multiplier phototube 2 mounted on an arm 3 which swings vertically about horizontal pivot 4 near the objective lens. A constant rise cam 5 driven by motor 6 and gear 7 engages a follower pin 8 projecting from arm 3 thereby positioning the slit and phototube. A spring 9 maintains the pin 8 in contact with the cam.

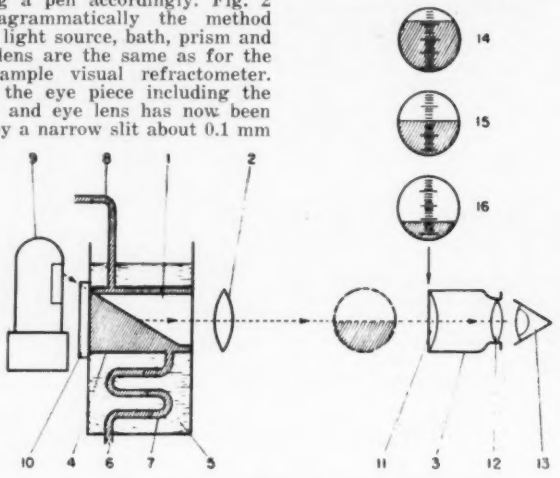



Fig. 1. Principle of Flowing Sample Visual Refractometer.

(1) Refractometer Prism
(2) Objective Lens
(3) Eye-piece
(4) Sample Cell
(5) Constant-Temperature Bath
(6) Sample Inlet
(7) Heat Exchange Coil
(8) Sample Outlet
(9) Sodium Arc Lamp
(10) Window
(11) Scale Lens
(12) Eye Lens
(13) Eye
(14), (15) and (16) Appearance of Field for Samples of Low, Medium and High Refractive Index Respectively

Voltage source 10 and voltage divider 11 provide an adjustable D.C. voltage which is impressed across the customary 10-step voltage divider (not shown) to provide the dynode and anode voltages for the phototube. The phototube output current passes through line 12 to microammeter 13 and thence through load resistor 14 returning through line 15.

The phototube output voltage produced across resistor 14 is opposed by a small bucking voltage produced by dry cell 16 across the voltage divider formed by resistances 17 and 18. The difference voltage E between the phototube output voltage and the bucking voltage is applied to amplifier 19 driving motor 6. The amplifier and motor are of the types used in self-balancing potentiometers. The amplifier contains a synchronous chopper converting the D. C. signal E to 60 cycle A. C. which is amplified and applied to one winding of the phase sensitive motor. Thus the cam turns clockwise when the phototube output voltage exceeds the bucking voltage and counter-clockwise when the phototube voltage is less than the bucking voltage.

By adjusting voltage divider 11 the phototube sensitivity can be set to make the phototube output voltage greater than the bucking voltage when the slit is up in the light field and less than the bucking voltage when the slit is down in the dark field. The slit will then move down when it is in the light field and up when it is in the dark field and will consequently maintain itself always in coincidence with the light-dark boundary.

It is now only necessary to couple a pen to the slit to record its position or some function of its position. This is accomplished by means of cam 20 driving the spring-loaded pen arm 21 which positions pen 22 on the clock driven chart 23. By a suitable choice of chart rulings and cam shape the pen can then record the position of the light-dark boundary in arbitrary units such as used in the flowing sample visual refractometer, or it can record refractive index or, if desired, it can record chemical concentration of a particular type of sample. By changing the cam, part or all of the scale can be compressed or expanded to suit the application.

## Adjustment of Phototube Sensitivity

Theoretically, in an ideal critical-angle refractometer the dark field would be jet black and completely free of light—a very desirable condition if it were attainable. Actually there is always some light in the dark field due to imperfections in the optical system, scattering and reflections from various surfaces, etc. However, under favorable conditions in a well constructed instrument the brightness ratio between the

Note:—Statements and opinions advanced in papers are to be understood as individual expressions of the authors and not those of the Society.

*Presented at the Fourth Annual Conference of the Instrument Society of America, Sept. 12-16, 1949, St. Louis, Mo.

†Physical Research Laboratory, The Dow Chemical Company, Midland, Michigan.

light and dark fields is at least 10 to 1 and may be as high as 100 to 1.

Fig. 3 shows the type of curve obtained when phototube output voltage (which is proportional to field brightness) is plotted against slit position as the slit moves across the light-dark field. Note that the phototube output with the slit in the upper part of the bright field is relatively high (in this case about 11 mv) and falls off as the slit approaches the light-dark boundary. At the boundary the slope of the curve (rate of change of output voltage with slit position) becomes very steep but still remains finite. The gradual falling off in field brightness as the boundary is approached is not readily observed visually. It is caused by increasing reflection losses and decreasing effective aperatures as the rays striking the liquid-glass interface approach more and more closely to grazing incidence.

The curve also shows the brightness of the dark part of the field to be fairly constant from the light-dark boundary to the bottom of the field. Actually it has been provided for performing this adjustment automatically at regular intervals. Thus less attention of the operator is required and greater accuracy is assured.

The operation is simple and somewhat analogous to the familiar automatic standardizing function on a self-balancing potentiometer. Referring to Figs. 2 and 3, an automatic adjustment is performed every 10 minutes as follows: A small motor energized by a timer performs three functions: (1) By means of a cam (not shown in Fig. 2) arm 3 is shifted downward moving pin 8 away from cam 5 and bringing the slit into the dark field, (2) A switch in the bucking voltage circuit reduces the bucking voltage to one-half its normal value, say 1 mv, and (3) A clutch couples voltage divider 11 to pen motor 6. As a result of the above changes, if the dark-field phototube output is not equal to one-half the normal bucking voltage the divider will be turned slightly until this equality is established. After a few seconds the clutch is disengaged, the bucking voltage is restored to its normal value, the slit is returned to the light-dark boundary, and the instrument goes on recording.

The entire adjusting operation described above is performed in one-half minute. Ordinarily the amount of adjustment required is insignificant and produces no perceptible deviation in the pen position. By making the adjustment as often as every ten minutes the instrument will operate satisfactorily even under abnormal conditions when the dark-field illumination is changing rapidly, for example, during the warming-up period of the sodium arc lamp.

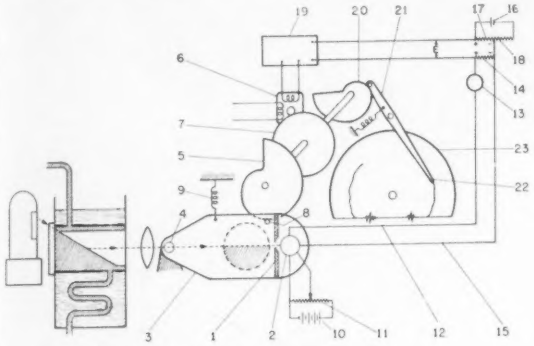



Fig. 2. Principle of Recording Refractometer.

(1) Slit
(2) Multiplier Phototube
(3) Slit Arm
(4) Pivot
(5) Main Cam
(6) Motor
(7) Gear
(8) Cam Follower Pin
(9) Spring
(10) Voltage Source
(11) Voltage Divider
(13) Microammeter
(14) Phototube Load Resistor
(16) Dry Cell
(19) Amplifier
(20) Pen Cam
(21) Pen Arm
(22) Pen
(23) Chart

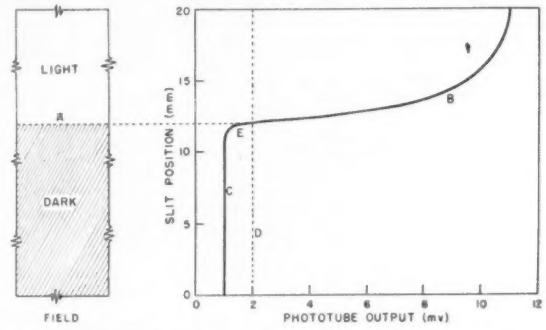



Fig. 3. Phototube Output With Slit in Light and Dark Parts of Field. (A) Light-dark boundary; (B) Phototube output, slit in light field; (C) Phototube output, slit in dark field; (D) Magnitude of "Bucking Voltage."

may increase or decrease slightly as the bottom of the field is approached. The sharpness of the break in the curve at E is closely related to the "sharpness" of the dividing line as observed visually.

The line marked D indicates the magnitude of the bucking voltage. In order for the slit to follow the light-dark dividing line most accurately it is necessary that the bucking voltage line D cross the phototube output curve near its steepest point. Errors can result if this intersection moves too low toward E or too high toward B. It has been found quite adequate in most cases to simply adjust the phototube sensitivity to bring the dark-field phototube output voltage to a value of one-half the bucking voltage as shown in the figure. If the liquid being measured is one which gives a rather fuzzy line resulting in a relatively large radius at E, it may be better to adjust the dark-field phototube output to one-quarter of the bucking voltage. The adjustment is not fussy or critical.

This adjustment can be done manually by periodically shifting the slit and phototube into the dark field and adjusting voltage divider 11 in Fig. 2 to give the necessary current reading on meter 15. However, for convenience a means

## Use as a Visual Refractometer

Another refinement which enhances the value of the instrument is an arrangement permitting its use as a visual refractometer as well as a recording refractometer. Some of the advantages of this arrangement are:

(1) The sharpness of the light-dark dividing line can be observed visually. If the line is fuzzy or the contrast is poor between the light and dark fields due to dirty prism, incorrect illumination or other causes, this condition must be corrected before the most accurate results can be obtained, either visually or automatically.

(2) The automatic functioning of the instrument can be checked against the visual reading for purposes of calibration and testing.

(3) In case of failure of the automatic part of the refractometer (for example, due to a vacuum tube failure) the plant operator can take visual readings until the instrument is repaired.

An instrument to function both visually and automatically must be equipped with the eye piece of Fig. 1 as well as the slit and phototube combination of Fig. 2. Because the slit and phototube occupy the same position in Fig. 2 that the eye-piece does in Fig. 1, a right-angle total-reflecting prism was used to deflect the beam and permit re-locating the slit and phototube in a manner to be described presently.

Fig. 4 is a somewhat diagrammatic cut-away view showing the general arrangement of parts in the instrument. This drawing shows the reflecting prism 13 which permits moving the slit and phototube to the positions shown where they cannot interfere with the eye piece. Slit arm 11 which carries the reflecting prism, slit and phototube is shown up in position for automatic operation where it can be moved up and down by the main cam 19 bearing against the cam-follower-pin 18 attached to the back side of the slit arm.

It should be noted that cams 19, 20 and 21 having different functions turn about the same center on concentric tubes and bear, one at a time, against pin 18 but are independently driven. To show the cams more clearly the width of the box and the bath (parallel to the cam axis) is exaggerated.

In order for the light from the objective lens to focus on the slit, the total length of the optical path from the objective lens to the reflecting prism and thence to the slit is made equal to the distance from the objective lens to the scale lens 16.

To visualize the operation of this instrument one can think of the equivalent optical system produced by reflecting the slit and phototube in the prism 13 to give a "virtual slit" in the plane of the scale lens with a "virtual phototube" behind it, with the prism now removed. The motion of the slit arm 11 now moves this virtual slit up and down vertically in the plane of the scale lens to keep it in coincidence with the light-dark boundary, and the instrument performs in exactly the same manner as the one in Fig. 2. The pen cam (not shown) which is located outside the box and coupled directly to cam 19 keeps the pen in step with the slit.

When the instrument is used visually the knob 22 is turned to the right against a stop thus rotating cam 21 one-quarter turn causing it to bear on pin 18 and push arm 11 so far down that

prism 13 is entirely out of the light beam from the objective lens. Thus the objective lens and the eye piece now form a stationery rigidly mounted optical system exactly like that of Fig. 1. The observer placing his eye at the eye-piece then sees the familiar light-dark field and determines the refractive index by reading the position of the light-dark boundary on the scale lens. When the instrument is to be put back on automatic operation it is only necessary to turn knob 22 back to its counterclockwise limit allowing pin 18 to rise up against cam 19 when automatic operation will proceed.

The shifting cam 20 driven by the two spur gears at the back of the box drives the slit down to the edge of the dark field when the phototube sensitivity is automatically adjusted.

### Construction

The general appearance of the instrument is shown in the accompanying photographs. The case which is designed for flush panel mounting, houses the refractometer box located in the upper left corner, the power supply located directly below, and the amplifier placed in the upper right corner. The pneumatic control elements when used, are mounted behind the chart plate.

The refractometer box containing all the optical elements except the refracting prism is of thick welded construction for rigidity, with one side removable for access to the optical system. The interior is painted a flat black. Pivots and cam bearings are carefully fitted to avoid lost motion. Mounted externally on the right side of the box are the pen cam and pen linkage, the drive for the 12 inch chart and the voltage divider and associated parts for automatic adjustment of phototube sensitivity. Behind the chart plate are the pneumatic control elements coupled to the pen and provided with adjusting means for set-point, throttling-range, and reset-rate all accessible from the front.

The back end of the refractometer box extends through a hole in the rear of the instrument case. The bath, which is outside the case, is screwed to the rear of the refractometer box. It is a self contained unit consisting of a hollow brass casting about 2 x 6 x 10 inches fitted with a motor-driven stirrer and a thermostat controlling a heater which holds the temperature constant within ±0.2°C. A copper coil provides for cooling water if needed. A ⅛ inch bore copper tube 12 feet long coiled in the bath brings the sample stream substantially to bath temperature before entering the cell. The prism is held by lithium and glycerine cement in a close-fitting brass sheath which in turn is soldered to the cell, affording a permanent, rigid and leak-tight mounting capable of operating under sample pressures of 75 psi.

The Bausch and Lomb dipping refractometer is supplied with a series of six prisms to cover a range in refractive index from 1.33 to 1.54, each prism covering a span of about 0.04 units. In the recording refractometer, since the prism is rather permanently mounted in the bath, a change of range is accomplished by substituting a different bath having the proper prism. This is a simple field operation.

Locating the bath outside the instrument case facilitates piping the sample to and from the instrument, affords easy access to the window and prism for cleaning, and avoids getting liquid into the case in the event of a leak.

The power supply, a simple little half-wave rectifier, provides 150μ A at 1500 volts for the phototube. A small meter provided with a range switch indicates the voltage to the phototube and its current output.

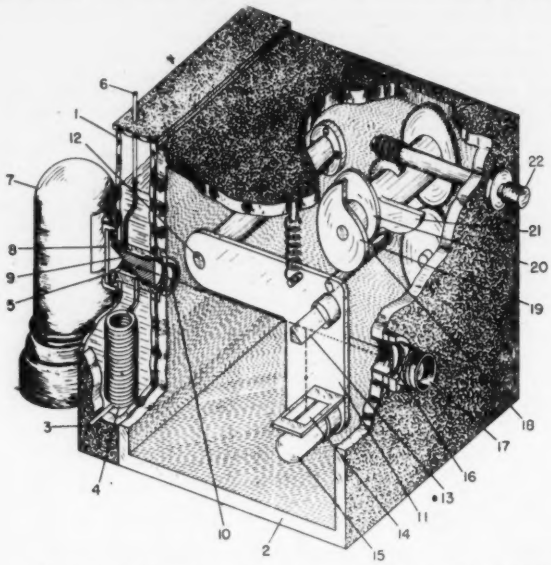
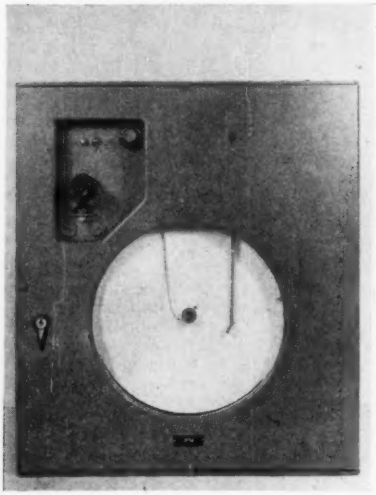
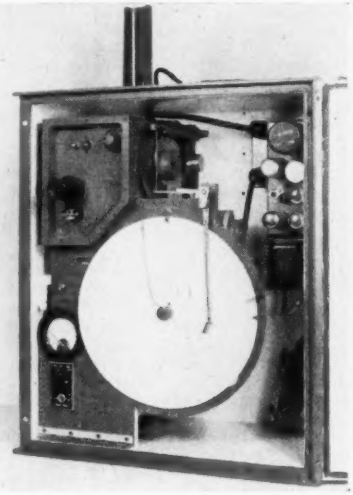



Fig. 4. Optical System and Parts Arrangement in Recording Refractometer (Diagrammatic).

(1) Constant Temperature Bath
(2) Refractometer Box
(3) Sample Inlet
(4) Heat Exchange Coil
(5) Sample Cell
(6) Sample Outlet
(7) Sodium Arc Lamp
(8) Window
(9) Refractometer Prism
(10) Objective Lens
(11) Slit Arm
(12) Pivot
(13) Reflecting Prism
(14) Slit
(15) Phototube
(16) Scale Lens
(17) Eye-piece
(18) Cam Follower Pin
(19) Main Cam
(20) Shifting Cam
(21) Visual Cam
(22) Visual Knob





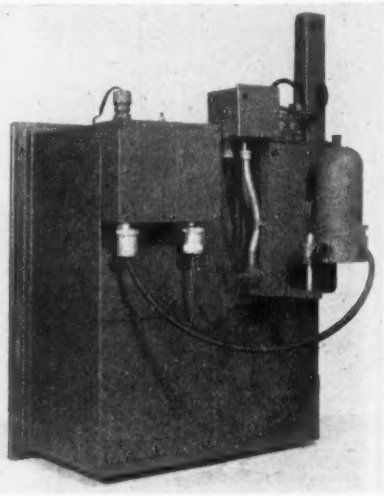


Fig. 5 (left) Front View of Recording Refractometer; Fig. 6 (center) Inside View; and Fig. 7 (right) Rear View.

To facilitate construction and to make field servicing easier, the various units; including bath, refractometer box, power supply and amplifier are interchangeable and readily removeable from the case by taking out three or four screws and pulling a cord plug connected to a central terminal box. Thus, any servicing that may involve more than merely cleaning the prism or replacing a vacuum tube can be easily handled by simply substituting a spare unit for the questionable one which is then brought to the shop for checking.

### Applications and Results

Conceivably, the recording refractometer might be used on any process liquid where refractive index measurements of ordinary laboratory accuracy can adequately show the composition. The potential applications are therefore varied and numerous. The recorders have already been used on many different materials. These include mixtures of vinyl and vinylidene chlorides, combinations of glycol derivatives, mixtures of styrene with ethyl benzene and combinations of substituted styrenes with their corresponding saturated compounds.

One controller application is in connection with a continuous fractional distillation to separate a substituted styrene from its parent material. The boiling points are only 13°C apart but the refractive indexes of the components differ by 0.0455, enough to shift the refractometer pen full scale. With the previous conventional method of operation where a temperature controller on the column controlled the steam to the reboiler, the results were erratic and the separation was poor. With the present method in which a constant steam pressure is maintained on the reboiler and the reflux rate is automatically controlled by a refractometer measuring the concentration part way up the column, the operation is smooth and the separation very satisfactory. This installation has operated more than a year with very little maintenance.

Good operation of the instrument requires that the refracting prism be kept clean. To clean the prism the window is screwed off and the prism swabbed with a piece of lens tissue, an operation requiring only a few minutes. The need for cleaning is apparent by viewing the light-dark field visually. With some liquids like vinyl chloride which tend to form deposits on the glass, cleaning must be done every few days. With some other liquids like the styrenes, cleaning is almost never required.

The life of the sodium arc lamps, while rather variable, averages three to six months operating continuously. The dry cell supplying the bucking voltage lasts several months. Other maintenance items include keeping up the water level in the bath and very infrequently replacing a tube in the power supply or amplifier.

The slit if moved away forcibly from its normal position coinciding with the light-dark boundary will return quickly and duplicate its original position to better than ± 0.1 scale lens division corresponding to a change of ± .00004 in the refractive index. Day to day discrepancies between the pen and the visual reading are greater than this due to variable distribution of light in the field, differential thermal expansion of the parts, etc. Under good operating conditions these discrepancies can quite easily be held to less than ± 1.0 scale lens division corresponding to a difference in refractive index of ± .0004 and a pen displacement of ± 1.0% of scale using the most common pen range.

In conclusion, a recording critical-angle refractometer has been developed and shown to be practical for recording and controlling liquid concentrations in the plant.

*Acknowledgements*: The development of this instrument was accomplished only by the cooperation of many people. Particularly valuable was the work of Messrs. P. Hargash, L. T. Finlayson, V. W. Rogers, and M. L. Boshaw of the Dow Chemical Company's Research Laboratory, L. Townsend now of the Michigan Chemical Company, and B. D. McPeake of the Modern Metalcraft Company.

### References

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# Rocket Instrumentation*

By GEORGE R. CARLSON†

ROCKET instrumentation referred to in this article covers instruments used in the development of solid fuel rockets. The quantities measured in this development are thrust, torque, and pressure as a function of time. In setting up the requirements for measurement of these parameters, it proved extremely valuable and economical to use instrumentation with large safety factors in frequency response and accuracy.

One major factor in design was the requirement of static response in the equipment. This requirement arises from the fact that the duration of burning in the test rocket is one or more seconds. At the high end of the frequency spectrum, the limit is set by the rise time of the pressure and the consequent rise time in thrust and torque. This rise time is normally in the region of fifteen milliseconds. If an attempt is made to evaluate the cause of blow-ups which occasionally occur, it is necessary to consider a much faster rise time. In this case, however, the pressure is the only one of the parameters which requires a higher frequency response from the measuring equipment.

The pressure gage used is a ferrule type strain gage—developed originally at Aberdeen Proving Ground for the purpose of studying the internal ballistics of guns. These gages have been used extensively for measuring pressure rises of one to two milliseconds,

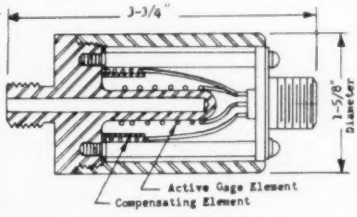


Fig. 1. Pressure Gage.

and give trouble only when the pressure rise approaches ten microseconds in duration. In gun tubes the pressure is often as high as twenty to thirty thousand pounds per square inch, while in these rockets the pressure is only a few thousand pounds. The pressure gages have been modified to adapt them to the special needs of this instrumentation.

One difficulty with temperature compensation, encountered early in the work, is that the original gages used contained only one strain wire winding. Temperature compensation was attempted by using a second gage in close proximity to the first but not subjected to pressure. This scheme proved extremely successful for measurement of pressure in gun tubes where the total measuring time is about ten milliseconds.

The ambient temperature changes are thus well compensated. In the rocket, when the burning time began to approach a second, it was necessary to compensate for temperature changes in a different manner. A strain wire winding was placed on a cylinder concentric and external to the pressure ferrule. This has proved to be completely satisfactory for temperature compensation for times up to several seconds. The gage as finally developed is shown in Fig. 1. At no times have the pressure rise times been so short as to excite the gages to oscillation. The result has been pressure records of very good quality which are easy to read and interpret.

The thrust stand proved to be an interesting development in that a high natural frequency was obtained. The rocket attached to an adaptor base rests on a supported cylinder. The cylinder is supported axially at the center of three tension straps located around the periphery of the cylinder. These tension straps are springs for the system; they are pre-stressed to a load greater than that to be measured. During the measurement the thrust of the rocket reduces the load on one half of each strap and increases the load on the other half. Strain gages are placed on

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both sides of the tension straps in order that any bending which may occur will be cancelled. The gages are connected in such a way that the average load appears as a signal to the amplifiers.

The adaptor base is guided and supported on bearings in such a manner that it is free to rotate on the supported cylinder. This is done in order to make torque measurements possible. The natural frequency of this thrust stand with rocket and adaptor base is about 330 cycles per second. The weight of the moving elements is 25 pounds. Thrust measurements with this setup are precise, since only occasionally is there a detectable excitation of the natural frequency of the stand.

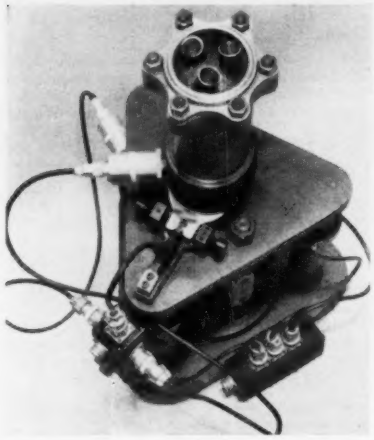

Fig. 2. Thrust stand and test motor ready for firing.

The measurement of torque has proved to be more difficult. If the period of the transient quantity to be measured is defined as equal to four times the rise time of that quantity, it is possible to make comparisons of various systems on the basis of period or frequency response. For measurement of thrust it was practical to make the period of the system about one-twentieth of that defined by the thrust rise time, whereas the design used for the torque measurement did not permit anything like this factor of safety. This might be attributed to the fact that only a small percentage of the rocket energy is used to produce torque and thus a soft spring is indicated. The torque is measured by attaching a radial arm to the adaptor base. This arm deflects a cantilever beam on which are mounted strain gages connected to measure bending of the beam. The cantilever beam is the spring system in this case. The first beam used was selected to give a signal comparable in magnitude to that from the thrust system. The natural frequency proved to be only 27 cps. This system gave records that were impossible to analyze. The cantilever beam then was changed to one having a natural frequency of 60 cps. This proved to be about as stiff a cantilever as could be used without redesigning the system. Again the records proved to be unacceptable, in spite of the fact that a factor of four in the period was available. Design is currently in process to decrease the period by an additional factor of four or five in order to obtain performance comparable to the thrust element. The thrust stand with a test rocket is shown in Fig. 2.

A four-channel cathode-ray oscilloscope (CRO) recording system was designed and constructed by the Electrical Engineering Department of Armour Research Foundation to meet the instrumentation requirements of the rocket, launcher, and projectile development programs being conducted by the Applied Mechanics Research Department. This system will record up to four sets of data simultaneously. The apparatus is entirely self-contained, portable, and sufficiently rugged to withstand field service.

This system will record static and dynamic impulses from Baldwin-Southwark SR-4 type gages or other types of wire resistance gages. The gages are connected electrically in the form of a balanced Wheatstone bridge circuit. The bridge output signal is amplified through a direct-coupled amplifier and impressed across the horizontal deflecting plates of a CRO tube. The signal appears on the oscilloscope screen as a spot which deflects horizontally; the amplitude of displacement is directly proportional to the quantity being measured. The horizontally moving spot is photographed by means of a continuous film camera. The film travels vertically and records the data as a trace of measured quantity versus time. The system has an overall sensitivity of 1.4 millivolts per millimeter deflection on the film. The amplifiers have an upper frequency limit of about 70 kilocycles and the recording limit is 20 kilocycles with an amplitude of 9 millimeters peak to peak.

The four channels of this recording system are identical and consist of the following component units: terminal unit, bridge power supply, d-c. amplifiers, oscilloscope unit, amplifier power supply, oscilloscope power supply, interval-timer unit, sweep-generator unit, sequence-timer control, and recording camera.

The interval-timer unit establishes timing marks on the film record by flashing glow modulator tubes mounted on the oscilloscope panel. One tube may be flashed at a calibrated frequency of 500 or 1000 cps., whichever is desired, and is recorded by the camera as spots spaced one or two milliseconds apart. Another glow modulator tube is initiated by the action to be measured to provide a zero-time base on the film record. Shortly thereafter it continues to flash at a frequency of 100 cps.

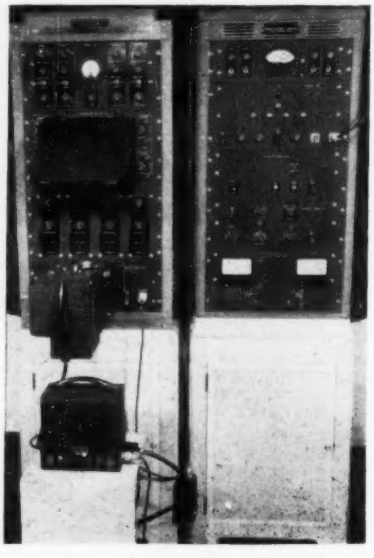

Fig. 3. Four-channel CRO recorder, front.

The terminal unit completes the bridge circuits of the external gages and provides the necessary zero-level balancing equipment as well as the trace calibration circuits.

The order of occurrence of the various steps in the recording process is governed by the sequence-timer control unit. The sequence timer controls automatically the following functions: initial film advance, record test identification number, start of camera motor for test run, operation of calibration trace relays, energizing of external starting signal, provision of a pre-determined time interval for recording data, stopping of camera motor, and de-energizing of sequence-timer control unit.

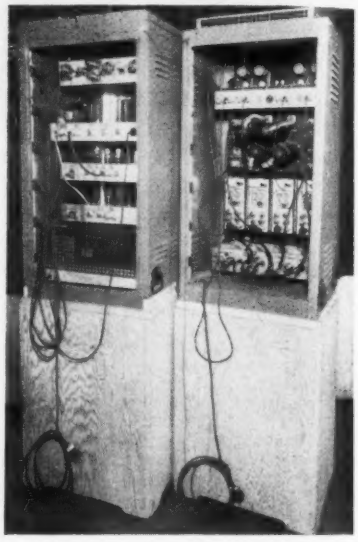

Fig. 4. Four-channel CRO recorder, rear.

The nine component units of the four-channel oscilloscope recording system are mounted in two steel cabinets measuring 43 by 22 by 18 inches. The steel cabinets are supported on separate wooden base cabinets through suitable vibration and shock-proof mounts to protect the electronic equipment. The base cabinets were designed to position the apparatus at a convenient height for manipulating the controls and for viewing the oscilloscope screens during adjustments. The base cabinets are mounted on rubber-wheeled casters to facilitate handling.

All nine units are rack mounted and are accessible through hinged rear doors for servicing and all internal adjustments. The one exception is the oscilloscope power supply which is shielded by a screen and interlock switch to protect the operator from the high voltages. This unit must be removed from the cabinet for any internal adjustments.

Each amplifier channel is a separate

plug-in unit and may be removed without disturbing the operation of the other three channels.

The component units are arranged in the steel cabinets to provide direct inter-unit connections and to provide, at the same time, the proper height and spacing for ease of operation. Each steel cabinet is provided with a standard 115-volt, 60-cycle, receptacle strip mounted vertically inside the rear right hand corner. The component units in each cabinet obtain external power by plugging into their respective receptacle strip. Consequently, only one line cord from each cabinet is connected to an external power source.

The arrangements of the various units in the cabinets is shown in Fig. 3 and 4. A specially designed mirror assembly is mounted on the front panel of the oscilloscope unit in order that the camera may be rigidly attached to the cabinet without excessive overhang. A flexible bellows (not shown) between oscilloscope mirror and camera permits operation of the unit in a well lighted area.

This equipment has performed with a minimum of service after the initial testing. This instrumentation is now being used on a routine basis for rocket research. The records of thrust and pressure are such that the engineer evaluating the records does not and need not question the validity of the records and can concentrate on evaluation of the rocket performance. It is hoped that in the near future, the same can be said of the torque measurements. One fact is already apparent: If an undamped mechanical system is used as a simple link in a pulse measurement system, it is essential that the mechanical system have a natural period of at most one-tenth to one-twentieth of the period of the pulse.

# Instrument Shop Layouts*

By R. L. NICHOLS†

THE rapid growth of Instrumentation in the past few years has put many older plants in the position of having installed expensive equipment for which they have neither trained personnel nor maintenance facilities. Since instruments do not perform any "useful" functions, such as pumping, heating, cooling, etc., there is still a tendency in many places to consider them as not too important expense items; conveniences rather than necessities. Hence, the care of instruments has been in many cases delegated to anyone who could pick up a screwdriver, or at best was added, as a side line, to the duties of an electrician or pipe fitter.

Consequently the "Instrument Shop" was any unused corner or shack on which the "Instrument Man" might exercise squatters rights, and the equipment whatever he could salvage from the scrap yard. The picture is not overdrawn.

As Management has begun to realize that good instrumentation, functioning properly, can mean the difference between profit and loss in operations the instruments have begun to get more and better attention.

Instrument Departments have been set up in a wide variety of forms, ranging from a sub-department under the Power Engineer to a separate Section reporting directly to the Superintendent.

The duties assigned to the Department have also been diverse. All instrumentation, plus anything anybody thinks relates to instrumentation, or that nobody else wants, has been assigned to the Department. The Instrument Man, being anxious to build up his vocation, and being of necessity a versatile mechanic, has taken everything that was offered, and turned in a good job. The "fringe" activities often include such things as the maintenance and repair of steam traps, safety valves, truck radios, P.A. systems, intercomms, time clocks, bicycles, typewriters, adding machines, business machines, etc. Plant photography has been included.

All of this has added up to a need for good equipment and a suitable place to work. Management is recognizing that need.

## Requirements of Well-Planned Shops

As in any group of human beings, the quality of the work performed is strongly influenced by the morale of the group. Further, good morale cannot be built in a dirty, makeshift shop using poor or unsuitable equipment.

Instrument work is close, accurate work. "Visiting" among workmen cuts down on production and accuracy. Hence, a well designed shop will have its work areas arranged in a manner that will discourage "visiting" and avoid interruptions as far as possible. Fixed areas for each type of work performed, properly arranged for minimum handling of equipment and no interference with other areas are fundamental in good shop design.

The Shop should include at least ten major areas: office, stockroom, tool room, storage, cleaning, heavy-work (valves, etc.) light-work (meters gages), electrical & specialty, electronic, training.

Various areas may be combined in the smaller shops. Larger units may need additional space, for example, storage areas for light and heavy equipment not in service; areas assigned to development work, etc.

The floor-space required for each area will be determined by the nature of the work performed in that area; the number of instruments serviced and the equipment furnished the mechanic who does the work. For example:

Tearing down and rebuilding control valves, if done on a floor or bench, using hand tools, drive wrenches, mauls, etc., will require more space and more man-power than the same job done on a valve-holding jig, under a jib crane, and using impact wrenches or other air-driven tools where indicated.

## Over-all Arrangement

The writer prefers an essentially square over-all outline for the Shop, although some very good arrangements have been worked out using rectangular outlines. Fig. 1 is an example of the latter.

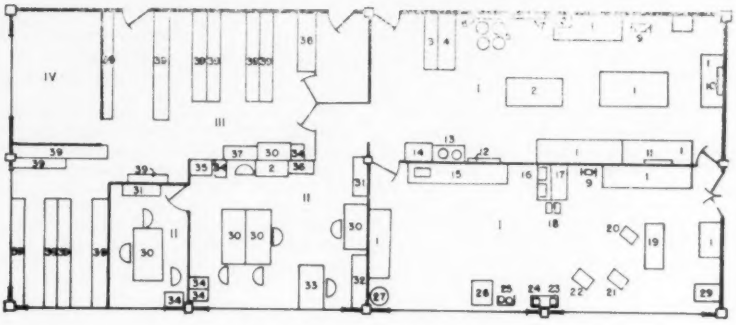

Fig. 1. Rectangular Building—Good layout.

The right hand half of the building is divided into two major shops, both marked I. The upper half is equipped for light work, calibrating and testing devices, etc. The lower half is equipped for the heavier work, and includes machine tools, welding equipment, caustic cleaning tank, etc.

The areas marked II are office space. The outer office has desks and files for assistants, engineers, clerks, etc. The inner office serves the Department head.

Spare instruments and parts are kept in area III, which has service counters for both shop and outside men.

Area IV is a class-room.

An early arrangement of the writer's shop is shown in Fig. 2. It is an excellent example of poor arrangement. The layout was influenced by the floor plan of the existing building, the war, the employment of women in the shop, and the writer's lack of experience.

Typewriters, potentiometers, gages, clocks, electrical and electronic devices were worked in room 4, mostly by women. Access to this area was through the office, room 3, which served the Depart-

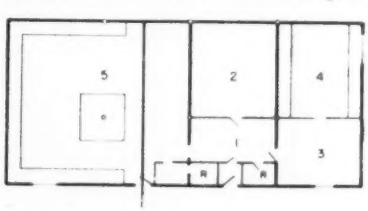

Fig. 2. Rectangular Building—Poor layout.

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†General Foreman Instrument Department, Magnolia Petroleum Co., Beaumont, Texas.

ment head, his assistant, and clerk. While this arrangement cut down on visiting between the men and women in the Department, it also made the office a public passageway, which was not good.

The stockroom, area 2, was, and still is, quite satisfactory. With it was combined the toolroom. The entry, area 1, is still used by the night trouble shooters as "home office." The double door entrance was a "black out" arrangement, but is now an integral part of the heating and ventilation system.

The heavy shop, area 5, was fair. The one big bench near the center of the room handled most of the meter and valve work. Temperature and pressure instruments, thermocouple manufacture, drill pres, grinder, etc., were assigned bench space around the walls. Bicycle repair (a major war activity!) shared the open floor space with valve and meter storage. The monorail shown extending through the door was little more than a device for loading and unloading heavy material and valves.

When the Shop was increased to its present size, a much better floor plan was worked out, Fig. 3.

Area 1 remains the entry. It contains the night desk, chairs, gas line control panel and "coke" machine.

Area 2 is now stockroom only, with a single combined door and service counter. A desk and typewriter, and a card file for continuous inventory are installed for the stock room clerk.

Area 3 is clerical and engineering. Desks are provided for orifice calculations, typing, and for specifications and estimates. The general catalogue file and instrument record file are in this room. A drafting table and supply cabinet complete the furnishings.

Area 4 is the supervisory office. Desks are provided for the Department head, assistant, and shop foreman. Clothes lockers, book cases, files and sufficient chairs for committee meetings or conferences are available.

A balcony runs around three sides of area 5. Individual lockers and tool boxes are stored here.

Below, to the left of the front door is the job clock. In the left front corner is the gasometer and gas meter repair bench. Just north of this, against the front wall is the refrigerator and water cooler repair section.

Area 11 is for cleaning and draining. It has a grating floor over a slight depression which drains to sewer.

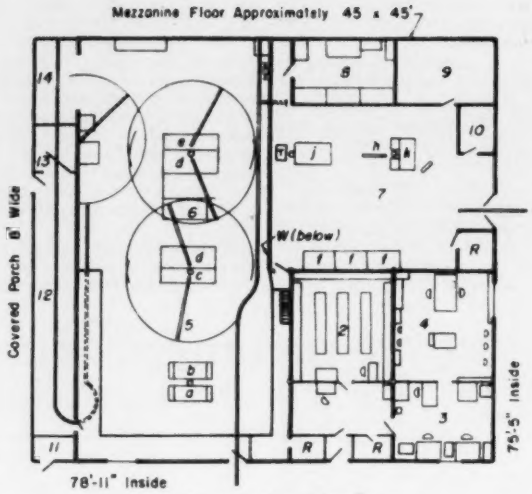


Fig. 3. Square Building—Good layout.

Area 12 is heavy storage. Steam traps, displacement meters, large valves and other heavy items are stored here. Areas 11 and 12 are combined behind one cyclone fence under a shed roof which covers areas 11, 12, 13 and 14.

Area 13 is for heavy cleaning. Caustic vat, high pressure water, and steam hose are available here in a section floored, like area 11, with grating over a depression drained to sewer. Attention is called to the fact that all cleaning is done outside of the main shop.

In area 5, "a" is the pressure gauge repair and calibration bench, "b" is the temperature bench. To the right of these, under the balcony, are the water cooler, stretchers, burn kits, and other safety equipment.

To the left, under the balcony, is the displacement meter testing and repair area.

"c" is the differential meter repair and calibration bench. Between b and c rollaway platforms carry material received or ready to go, and jobs temporarily side-tracked.

"d-d" are general work-benches. Directly under 6 is equipment for steam trap repair.

Bench "e" and the area under its jib crane are for control valve maintenance and repair. Trucks bringing in heavy equipment come through area 14 and the large roll door to make deliveries. If equipment is dirty it is picked off the truck in area 14 and deposited in the proper cleaning spot in area 13. Trucks equipped with two-way radio also come inside for radio servicing.

Against the back wall is the thermocouple manufacturing equipment and in the northwest corner the welding bench and grinder.

Just inside the truck door is the spray painting booth, and next to it the drill press and air driven punch. The wall area adjacent to the drill press is reserved for a hoped-for lathe and shaper.

Two monorails and five jib-cranes equipped with half-ton air hoists make man-handling of heavy equipment entirely unnecessary in this area.

Area 7-8-9-10 is a mezzanine floor. A short monorail projects out through the door in the north wall over a railroad track. The rectangle marked "T" is a trap door served by an air hoist for transferring material between floors.

Area 7 is used for general repair and rebuilding of control instruments. At "f" are general work-benches. "h" is a small lathe. "j" is a table on which are assembled a drill press, die-filer, grinder and polishing wheel. Bench "k" with its associated storage cabinets and easels is used by the mechanic who does special development work. Special instruments (Strobotac, Vibration Meter, etc.) are stored on a table along the west

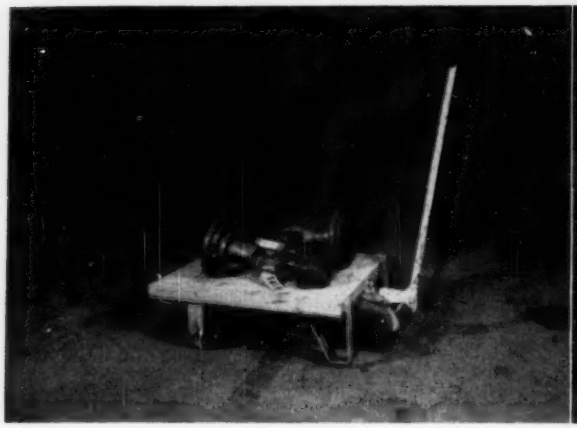

Fig. 4. Rollaway skid.

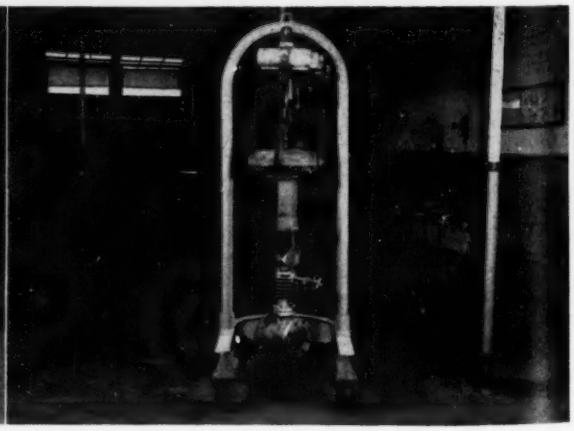

Fig. 5. Special "horse-collar."

Fig. 6. Gage Tester—Comparison Type, Bench.

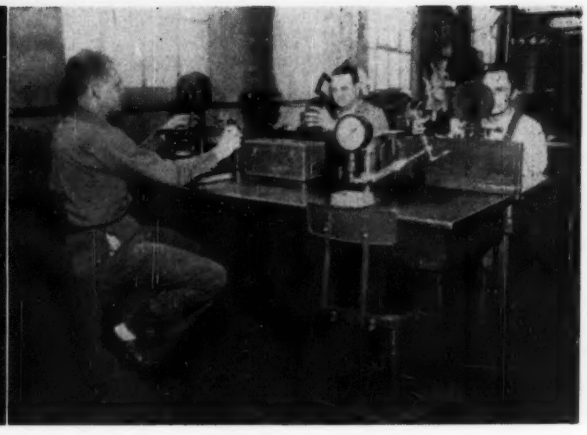

Fig. 7. Gage Tester—Dead Weight.

wall of the area. The open portion of the area is at present used for classroom purposes.

Area 8 is the electronic specialties room. Truck radios, intercomms, sound systems and various other electronic devices are serviced here.

Area 9 is at present a well-equipped dark room which is to be relocated in the near future. This area will then be used for class-room purposes.

Area 10 is the clock-repair and engraving room. It also serves as a tool-room for the mezzanine floor only.

Areas marked R are rest rooms.

Beneath the mezzanine floor is a store-room for instruments awaiting repair, or new instruments bought for special jobs. The area is served by two monorails. The end of one is shown near the welding bench.

The main shop tool room is located along the east wall of this area, with a service window at "w". A small sand-blast room is located in the north-east corner of the area.

In addition to the monorails and jib-cranes the shop is equipped with a number of rollaway skids (Fig. 4) and what we call, for want of a better name, the "horse-collar" (Fig. 5). This last item can go anywhere in the shop, pick up anything weighing less than 1500 pounds, and roll it away.

The shop serves a crew of 47 men who maintain approximately 3000 instruments, of which 1000 are circular chart recorders or recorder-controllers. 1500 control valves, 7000 pressure gages, un-numbered steam traps, 140 clocks and timers, 40 electric water coolers, 4 air conditioners, 6 refrigerators, 40 intercommunication sets, 12 two-way truck radios, 4 P. A. systems are among the items serviced and maintained by the group.

With some rearrangement and additional equipment the present floor space would be sufficient for nearly double the items presently serviced.

## Space Requirements

As previously stated, the type of equipment used strongly affects space requirements. An excellent example is gauge handling equipment. Fig. 6 shows our gage bench. The whole set-up, including stack-boxes for storage, occupies a space 3 feet by 8 feet. Allowing a strip 3 feet wide along the front for the mechanic (or mechanics, since two can work comfortably), the required area for this set-up is 6 feet by 8 feet. It may be set against a wall or in the middle of the floor. Aisle space must be figured in addition to that given.

Fig. 7 is another style of gauge set-up. This one requires a minimum of 6 feet by 10 feet. This set-up, plus a high pressure test stand, serves approximately 20,000 gages.

Fig. 8 is still another style of gage test panel. The number of gages served is not known.

These three pictures should drive home the point that in the design of an Instrument Shop as in any other shop the first step is to determine the scope of the work to be performed; the second is to select the equipment to be used, and the third is to design the building to properly house the equipment, with due consideration for the comfort and convenience of the workmen, and probable future expansion.

Fig. 9 shows a work-bench for valves. This bench is 24 inches high, 30 inches wide, and need not be more than six feet long. However, floor space 6 feet wide should be left in front of the bench, and 2 feet at each end, making a total space of 8 feet 6 inches by 10 feet.

Fig. 10 is an arrangement of small machine tools on one bench. This bench is 4 feet by 8 feet, and provides a work space roughly 3 feet by 6 feet for use by anyone who may be using the machines. The usual 3 foot work space is required on the sides and one end.

Fig. 11 is an arrangement of small machines on individual stands. Design of this area should follow standard machine shop practice.

To sum up, it would appear that a well designed shop should provide a minimum space 6 feet by 6 feet for each shop employee or shop activity, exclusive of aisles, storage space, tool rooms, stock rooms or rest rooms.

## Lighting

The building in which the writer's shop is situated was originally without

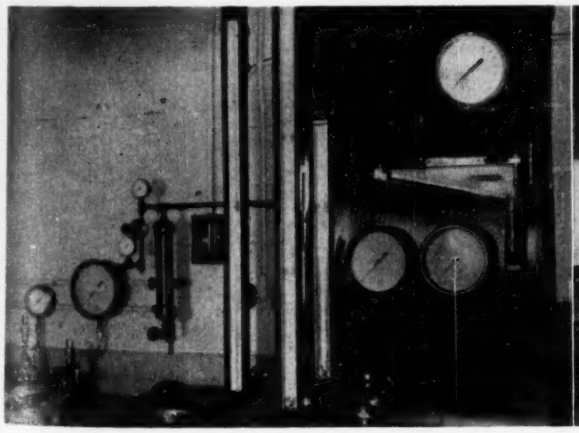

Fig. 8. Gage Tester—Comparison Type, Wall Panel.

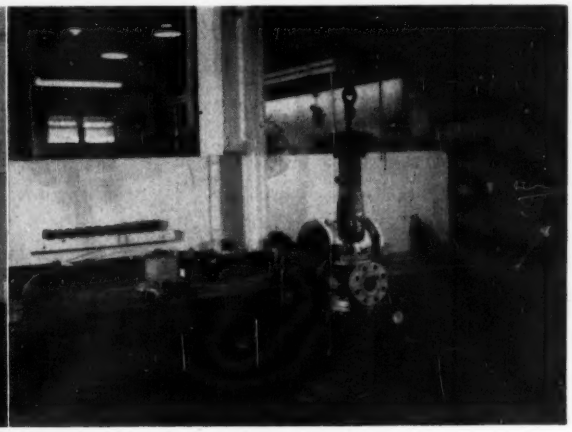

Fig. 9.—Valve work bench.

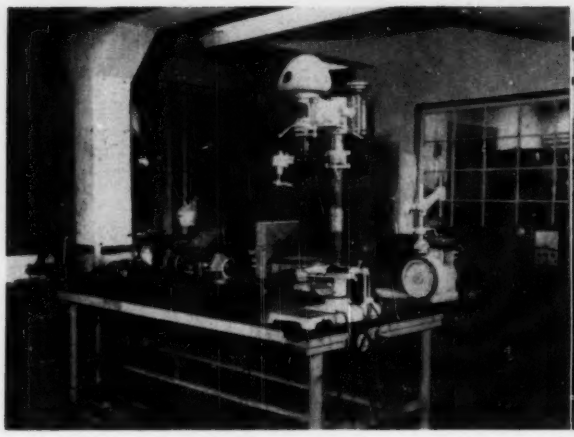

Fig. 10. Machine tool set-up.

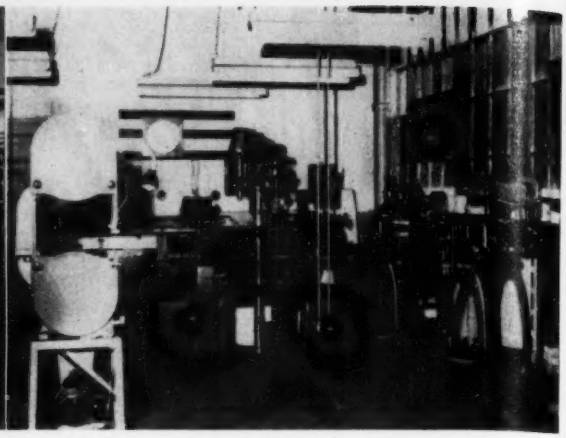

Fig. 11. Small machine tool area.

windows. In conformity with Army suggestions at the time, very few windows were cut in the walls. Fluorescent lights over benches and combined mercury and filament lamps in high bays provide even, unvarying, properly placed illumination which we believe to be preferable to daylighting.

### Ventilating

Roof vents, open in summer and closed in winter take care of high bay ventilation. In summer, air is forced through a water spray into the offices and out to the shop. The water spray removes all dust and cools the air about 4 degrees F. Air to the Electronics section is washed with chilled water which lowers its temperature about 8 degrees F. All other parts of the Shop are equipped with fans bearing directly on the work areas. Exhaust fans have been tried and found unsatisfactory. The writer does not favor air conditioning beyond conditions set out above.

### Heating

In winter, radiators replace sprays in the two forced air systems outlined above. Since both of these systems discharge into the main shop and the winters are mild, the only additional heat required is furnished by small radiators spotted near outside doors.

Proper lighting, ventilating, and heating are absolute musts for the efficient shop.

### Utilities

The Instrument Shop, more than any other, requires good distribution of utilities. It is not sufficient to put a few valves on the wall where one can connect a hose and get air or water, or a receptacle for 110 volts through an extension cord. Utilities should be brought to the point where they will be needed, either concealed in conduit or at least symmetrically placed with some degree of order.

The utilities furnished must include: Yard Air, Steam, Drinking Water, 110 V. A.C. Current, Sanitary Sewer.

Power requirements are usually under estimated. Electrical leads to and throughout the shop should be heavy.

Additional utilities that should be included are:
40 lb. Dry Air, Waste Sewer, Vacuum, 220-440 V. A.C. Current.

In short, the proper design of an Instrument Shop is worthy of the combined efforts of Engineer and Architect, assisted and advised by the man who runs one.

The writer wishes to acknowledge the assistance of Mr. L. C. Laird in securing pictures and data. Since one of the companies concerned preferred to remain anonymous, it was thought best not to name any.

# Inspection By Optical Projection*

By W. DeBOER†

THERE is an old adage which says, "Seeing is Believing." With the use of optical comparators, this truth is applied to gaging and inspection operations in both tool room and production applications.

The ability to "feel" or measure one or two thousandths of an inch is often an uncertain and tedious procedure. The sense of touch required in these operations often varies with an alertness, or lack of it, dependent upon the individual operator. The results have too often produced an undependable quality of product.

The optical projection method of inspection is probably the least understood of gaging procedures. Yet the experience in numerous plants has proven that in many instances of production to minute dimensional limits quality control can best be achieved by this method. In some instances where contours are involved, it is the only practical method.

The optical projection comparator utilizes a simple and practical method of projecting a magnified shadow of a part on to a viewing screen conveniently placed in front of the operator. The principle applied is to position a part at the focal point between a parallel ray light source on the one side and an accurate optical system of a known magnification on the opposite side. The shadow profile on the ground glass viewing screen of the part so positioned is then compared to a chart-gage screen or drawing on the viewing screen to determine if the part is within the maximum and minimum tolerance limits. Example: 0.001 inch magnified 20 times equals 0.020 on the comparator screen or 0.0001 inch magnified 62.5 times equals 0.00625 on the screen. Thus more than one person can simultaneously check the part with equal dependable accuracy.

The improved optical systems, better illumination, increased sharpness of image and freedom from color fringes, fuzziness and distortion over the entire screen area of the optical projection comparators, and contour projectors now available, have broadened considerably the utilization of the visual inspection method as a production tool for accurate time saving inspection of component parts to within critical tolerance limits.

By projecting an accurately magnified shadow, the optical projection comparator or contour projector, provides a means for seeing and measuring even "split thousandths." When scientifically coordinated staging fixtures and chart-gage screens are used with these optical projection instruments, even more rapid and accurate inspection is made possible.

The pitch diameter, lead, tooth angle, root diameter and outside diameter of many threads, taps, lead screws, worms, pinions or gears can be quickly and accurately inspected by optical projection methods.

Not only are external contour profiles of thousands of critical tolerance component parts being inspected by this method, but internal contours of such parts as lock valves and the noses of proximity fuses and obscured shapes of turbine and jet engine blades are also being checked by optical projection.

New fields of inspection utilizing the increased efficiency of surface illumination in contour projectors are now avail-

*Presented at the Fourth Annual Conference of the Instrument Society of America, Sept. 12-16, 1949, St. Louis, Mo.

†Plant Manager, Engineers Specialties Division, Buffalo, N. Y.

able. 1000-watt illuminators are used with the resultant greater sharpness and definition of images. This recent development has made possible easy gaging of surfaces or profiles, which due to their "hidden" locations has made inspection or gaging extremely difficult and often impractical.

The application of optical projection to production inspection has materially reduced the number of gaging operations as compared to mechanical gaging methods.

As many as 32 "go and no-go" dimensions have been checked by means of one co-ordinated staging fixture and one chart-gage screen at a single operation. The cost of inspection operations has been reduced where optical projection has been applied, because of simplification of operations, elimination of fatigue, reduction in number of operations, and the elimination of the customary replacement of worn gages. To the old adage of, "Seeing is Believing" as applied to inspection by optical projection methods can be added another truth, "There is no wear to a light beam."

## EMPLOYMENT SERVICE

*Forward your letter to INSTRUMENT SOCIETY OF AMERICA, 921 Ridge Ave., Pittsburgh 12, Pa.*

**SALES & SERVICE.** For motor operated valves, electrical timers, temperature controls (approximately 80 percent sales, 20 percent service). Should have good electrical foundation and training in electronics. Industrial plant experience in operation of measuring instruments highly desirable. Territory covers Northern New Jersey, New York City, Long Island and lower Hudson Valley. Must have car. Customers are industrial plants, equipment manufacturers, consulting engineers, etc. Salary $275.00 per month to start plus, car and traveling expenses. Box 285.

**ENGINEERS.** Electrical and mechanical experienced in development of processes and design of equipment and tooling for "ultra-precision miniature mechanisms." Also supervisory openings for top-caliber men with wide knowledge of latest developments applicable to production of one or more guided missile components. Interviews will be arranged near your home if possible. Manufacturer of guided missiles. Location California. Box 286.

**INSTRUMENT ENGINEER.** Experienced in the application, installation and operation of apparatus for continuous process plant control. Well known refinery engineering organization offers opportunity in New York Office to a top flight, field trained engineer. Salary commensurate with ability and experience. Write in confidence giving complete details of education, experience, salaries received, age and other pertinent data. Box 287.

**INSTRUMENT ENGINEER.** Graduate, 26-32, experienced in application and maintenance of instruments and controls in power plants. Position is open in engineering department of large utility company. Some traveling required. Salary $3600-$4500. Location New York. Box 288.

**INSTRUMENT PRODUCTION ENGINEER.** Electrical engineering training, experience in manufacturing, especially small aircraft-type indicating electrical instruments. Salary commensurate with technical ability and experience. New York area. Box 289.

**INSTRUMENT DESIGN ENGINEER** for design of electrostatic voltmeters, who is capable of calculating the electrical properties and designing the mechanical pivot mountings. Should have ingenuity in order to work on new methods of approach for completely new designs. Salary commensurate with ability. Location, Newark, N. J. Box 290.

**ELECTRICAL INSTRUMENT MECHANICS** having a knowledge of electrical meters and test equipment. Should be familiar with electrical circuits and be able to assemble and cali-

*Continued on page 406*

## Booth Allocations Made to 1950 Exhibitors

The Allocations Committee (Niagara Frontier Section) for the Fifth National Instrument Conference and Exhibit, met in Buffalo, N. Y., on February 20 and 21, 1950, for the purpose of allocating booths at the Exhibit to those past exhibitors who had made reservations during the thirty days of booth sale prior to February 20, 1950.

Of the 165 booths available, 104 were assigned to 64 exhibiting companies.

On March 6, 1950 the space was opened to general sale. As of March 20. 1950, 118 booths have been sold to 84 exhibiting companies. A list of the exhibiting companies follows and every indication points to a very successful exhibit.

| COMPANY | BOOTH |
|---|---|
| Aircraft Marine Products, Inc. | 413 |
| American Instrument Co. | 440, 442 |
| American Institute of Physics | 108 |
| American Meter Co. | 511, 513, 515 |
| Anders Co. | 405 |
| Assembly Products, Inc. | 222 |
| The Baker Co. | 324 |
| Barton Instrument Co. | 206 |
| Beckman Inc., Arnold O. | 234, 236, 238 |
| Biddle Co., James G. | 239 |
| Brooks Rotameter Co. | 423, 425 |
| Brush Development Co. | 415, 417 |
| Buffalo Meter Co. | 111 |
| Burgess Battery Co. | 318 |
| Century Geophysical Corp. | 118 |
| Climax Control Div., | |
| Black, Sivalls & Bryson Inc. | 213, 215 |
| Conoflow Corp. | 439, 441 |
| Consolidated Engineering Corp. | 107, 109 |
| Continental Equipment Co. | 209, 211 |
| Corry Instrument Co. | 222 |
| Cramer Co., R. W. | 438 |
| Davis Instruments Div., | |
| Davis Emergency Equipment Co. | 210 |
| DeZurik Shower Co. | 204 |
| Fisher Governor Co. | 429, 431, 433 |
| Fischer & Porter Co. | 101, 103, 105 |
| Frederic Flader, Inc. | 416 |
| Fulton Sylphon Div., | |
| Robertshaw Fulton Controls Co. | 337, 339, 341 |
| General Electric Co. | 301, 303, 305 |
| Gotham Div., | |
| American Mach. & Metals, Inc. | 340, 342 |
| Hammel-Dahl Co. | 501, 503 |
| Haydon Co., A. W. | 110 |
| Hays Corp. | 112, 114 |
| Helicoid Gage Div., | |
| American Chain & Cable Co. | 411 |
| Helipot Corp. | 234, 236, 238 |
| Hills McCanna Co. | 137 |
| Holtzer Cabot Electric Co. | 309 |
| Illinois Testing Labs., Inc. | 237 |
| Industrial Instruments, Inc. | 310 |
| Instruments Publishing Co., Inc. | 106 |
| J-B-T Instruments Inc. | 308 |
| M. S. Jacobs & Assoc., Inc. | 212, 214 |
| Jerguson Gage & Valve Co. | 241 |
| Kay Electric Co. | 404 |
| Kelley-Koett Mfg. Co. | 314 |
| Kieley & Mueller, Inc. | 407, 409 |
| Lapp Insulator Co. | 427 |
| Leslie Co. | 122, 124 |
| Magnetrol, Inc. | 113 |
| McAlear Mfg. Co. | 207 |
| Marion Electrical Instruments Co. | 240 |
| Meriam Instrument Co. | 315, 317 |
| Milton Roy Co. | 235 |
| Mine Safety Appliances Co. | 302, 304 |
| Miniature Precision Bearings, Inc. | 117 |
| Moore Products Co. | 435, 437 |
| Nash Engineering Co. | 401, 403 |
| National Technical Labs. | 234, 236, 238 |
| Nestor Engineering Co. | 324 |
| New Hermes Engraving Mach., Corp. | 224 |
| Palmer Thermometers Inc. | 319, 321 |
| Panellit Inc. | 201, 203, 205 |
| Permutit Co. | 226 |
| Physicists Research Co. | 121, 123, 125 |
| Photoswitch Inc. | 311, 313 |
| Precision Thermometer & Instr. Co. | 202 |
| Proportioneers Inc. | 218 |
| R-S Products Corp. | 419, 421 |
| Sanborn Co. | 216 |
| Shand & Jurs Co. | 323 |
| Sharples Corp. | 509 |
| Standard Electric Time Co. | 402 |
| Sticht Co., Inc., Herman H. | 322 |
| Superior Tube Co. | 115 |
| Telechron Inc. | 119 |
| Trerice Co., H. O. | 220 |
| Trimount Instrument Co. | 208 |
| Uehling Instrument Co. | 507 |
| Veeder-Root, Inc. | 505 |
| Wallace & Tiernan Products, Inc. | 307 |
| Weatherhead Co. | 330, 332 |
| Welch Mfg. Co., W. M. | 232 |
| Welwyn Electronic Components, Inc. | 306 |
| Wheelco Instruments Co. | 217 |
| Yarnall Waring Co. | 132 |

Only 35 booths remain to be sold as of April 6.

## Co-Sponsoring Societies Buffalo Conference

The six technical societies who met jointly with the ISA last year during the St. Louis Conference, have again expressed their willingness to cooperate with the ISA in co-sponsoring the coming 1950 Instrument Conference and Exhibit to be held in Buffalo, September 18-22.

These societies are: American Institute of Physics, Industrial Instruments and Regulators Division of the American Society of Mechanical Engineers, Instruments and Measurements Committee of the American Institute of Electrical Engineers, Institute of Radio Engineers, Scientific Apparatus Makers Association and the National Telemetering Forum.

Representatives of these societies met in Buffalo, February 20, and have begun arrangements for the 1950 Conference.

Chairman of the Committee on Co-Sponsoring Societies is Joseph Hildyard of the Niagara Frontier Section, ISA.

**Members of the Buffalo Conference Committee (all of the Niagara Frontier Section) who are making the arrangements for the annual meeting are left to right: Sam Gewin—Entertainment; Joe Hildyard, Cooperating Societies; Joe Serpa, Educational; Larry Kimber, Meetings and Properties; John Duthie, Employment; Jack Lawrence, Publicity; Graham Hill, Reception and Registration; George Kellner, Co-chairman Convention. Millard Shriver, Co-chairman Convention Committee and J. Akins, Allocation Committee, were not present.**

*Continued from page 405*

**brate meters and test equipment. Some machine shop experience desirable but not necessary. Give complete details of experience and background in first letter. Location Chicago, Illinois. Box 291.**

**INSTRUMENT ENGINEER with two to five years industrial instrment experience, preferably in the chemical field. Opening is with large chemical works in Texas. Salary commensurate with experience and background. Give complete details in first letter. Box 292.**

**SALES MANAGER By old established manufacturer of industrial thermometers, dials, recorders, air and electrically operated controllers. One experienced in instrumentation who can personally bring in good volume of new business also contact and keep present accounts satisfied. Location Chicago area. Give resume of experience in first letter. Box 293.**

## Section Secretaries, Meeting Data and Programs

**AKRON**
Fred Appel, 932 Columbia Ct., Barberton, Ohio. Tel: SH 3440
Fourth Tuesday, Meeting at 7:30 P. M., Akron Y.W.C.A.
April 25, "A tour of The Fourth National Instrument Exhibit," Slide Film No. 2.

**ALBUQUERQUE**
L. J. Paddison, 911 Parkland Circle, Albuquerque, N. M. Tel: 5-1806
First Monday, Meeting at 8:00 P.M., Science Lecture Hall, Univ. of N. M.

**ARUBA**
K. H. Walker, P. O. Box 389, c/o Lago Oil & Tranpsort Co., Ltd., Aruba, N.W.I.
First Tuesday, Meeting at 7:15 P. M.

**ATLANTA**
H. Kockritz, Fischer & Porter Co., 84 Peachtree St., Atlanta, Ga. Tel: CY 1269
Fourth Monday, Meeting at 7:45 P.M., Ga. Institute of Technology.

**BALTIMORE**
George B. Greer, 631 E. 36th St., Baltimore 18, Md. Tel: Chesapeake 6879
Second Friday, Meeting at 8:00 P.M., Engr's. Club of Baltimore.

**BATON ROUGE**
John Q. Bass, 1517 Longwood Dr., Baton Rouge, La.
Meeting at 7:30 P.M., L.S.U. Geology Bldg.

**BOSTON**
C. J. Nazzaro, 456 Central Avenue, Milton 87, Mass. Tel: CU 6-2479
Last Wednesday, Dinner at 6:30 P. M., Meeting at 7:00 P.M., Patten's Restaurant.

**CALIFORNIA**
D. C. Duncan, Helipot Corp., 916 Meridian Ave., S. Pasadena, Calif. Tel: SY 4-8439
First Tuesday, Dinner at 6:30 P. M. Meeting at 8:00 P. M.
May 2: Sound Slide Film No. 3.

**CENTRAL ILLINOIS**
H. F. Lange, 2101 W. Glen Avenue, Peoria 5, Ill. Tel: Peoria 5-4516
First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M.

**CENTRAL INDIANA**
H. F. Coffey, 4029 N. Temple Ave., Indianapolis, Ind. Tel: HU 5832
First Tuesday, Meeting at 7:30 P. M.

**CHARLESTON**
Claton A. Williams, 303 E. 9th St., Belle, W. Va. Tel: 927871
First Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Kanawha Hotel.
May 8, "Gadgets," R. D. Webb, Carbide & Carbon Chemicals Co.

**CHICAGO**
Floyd E. Ertsman, Rm. 1420 Fisher Bldg., 343 S. Dearborn St., Chicago, Ill. Tel: WE 9-0686
Third Tuesday, Dinner at 6:45 P. M., Meeting at 8:00 P.M., W.S.E. Auditorium.

**CHINA LAKE**
A. H. Staud, 209-B Entwistle, USNOTS, China Lake, Calif. Tel: 77882
Fourth Thursday, Meeting at 8:00 P.M., Michelson Lab, USNOTS.

**CINCINNATI**
Edward H. Muhleisen, 320 Durrell Ave., Cincinnati 15, Ohio. Tel: PO 1168
First Monday, Meeting at 8:00 P.M., Eng'r. Society Hqs.

**CLEVELAND**
R. M. Woodside, 332 Oakmoor Rd., Bay Village, Ohio. Tel: TR 1-4405
Fourth Wednesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Cleveland Eng'r. Society.

**COLUMBUS**
Orval Linebrink, c/o Battelle Memorial Institute, 505 King Ave., Columbus, Ohio. Tel: RA 5016
Third Thursday, Battelle Auditorium

**CUMBERLAND**
Clyde Babst, 225 Cecilia St., Cumberland, Md. Tel: 583-W
Tuesday after Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Algonquin Hotel.

**DETROIT**
Seymour Sterling, 13331 Linwood, Detroit, Mich. Tel: Tyler 5-1707
Second Wednesday, Meeting at 8:00 P.M., Rackham Bldg.
May 10, "Problems in Time Measurement," H. H. Barnum, H. H. Barnum Co.

**EASTERN NEW YORK**
W. R. McKegg, c/o Gen. Engrg. & Consulting Lab., G. E. Co., Schenectady, N. Y.
First Tuesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M.

**GULF COAST**
W. N. Sloan, E. I. Du Pont de Nemours & Co., Orange, Texas. Tel: 8411 Ext. 444
Third Tuesday. Meeting at 7:30 P.M., Lamar College.

**HOUSTON**
E. E. Kleir, c/o The Foxboro Co., 2518 S. Blvd., Houston 6, Texas. Tel: MA 6933
Last Monday, Meeting at 8:00 P.M., Engineers Club.

**KANSAS CITY**
L. E. Oberhelman, Standard Oil Co., Sugar Creek, Mo. Tel: MU 1227
First Tuesday, Meeting at 7:30 P.M., Univ. of Kansas City.

**LOUISVILLE**
H. C. Scherffius, 980 Palatka Rd., Louisville 8, Ky. Tel: Franklin 1265
Fourth Tuesday, Meeting at 8:00 P.M., Seagram Auditorium.

**MONTREAL**
S. J. Mizuhara, 1075 Allard, Verdun, Quebec, Canada. Tel: TR 3252
Last Monday, Meeting at 8:00 P.M. Mechanics' Hall.

**NEW JERSEY**
W. D. Archibald, 605 Westminster Ave., Elizabeth 3, N. J. Tel: Elizabeth 2-5529
First Tuesday, Dinner at 6:00 P. M. Meeting at 8:00 P.M., Essex House.
May 5, Spring Dance at Elizabeth Town & Country Club
June 6, "Users Requirements For Control Valves," W. H. Shellenberger, Std. Oil Dev. Co.

**NEW ORLEANS**
W. H. Haney, 2927 Music Avenue, New Orleans, La.
No Regular Date, Meeting at 8:00 P.M.

**NEW YORK**
Norman J. Cherry, P. O. Box 608, Merrick, L. I., N. Y. Tel: Freeport 9-4127
Last Monday, Meeting at 7:30 P.M., Statler Hotel.

**NIAGARA FRONTIER**
Mrs. James L. Martin, 697 Potomac Ave., Buffalo 9, N. Y. Tel: GR 1450
Fourth Monday, Dinner at 6:15 P.M., Meeting at 8:00 P.M., Institute of Arts and Sciences, Buffalo.
April 24, Round Table Discussion, Instrument Maintenance, also Sound Slide Film No. 1.
May 22, "How to Select a Control Valve," B. A. Irwin, Hammel-Dahl Co.

**NORTH TEXAS**
R. E. Byers, 6000 Lemmon Ave., Dallas 9, Texas

**NORTHERN CALIFORNIA**
M. A. Dimmick, 5607 Alta Punta, El Cerrito, Calif. Tel: Be 5-1095
Third Monday, Meeting at 7:30 P.M., Angelo's, Emeryville.

**NORTHERN INDIANA**
J. Baum Beckman, 547 N. Waller Ave., Chicago 44, Ill. Tel: ES 8-7776
Third Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M., Gary Y.M.C.A.

**OAK RIDGE**
John H. Clark, 230 Canton Hall, Oakridge, Tenn. Tel: 5-9142
First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M., Oak Terrace.

**ONTARIO**
John W. Huether, 311 Southerland Dr., Leaside, Ontario, Canada. Tel: HU-7114
Third Thursday, Dinner at 6:45 P. M. Meeting at 8:15 P. M. Friendship Hall, College St. United Church, Toronto

**PANHANDLE**
R. E. Harris, 228 Mays Bldg., Amarillo, Texas. Tel.: 31434.

**PHILADELPHIA**
C. W. Wood, 6908 Market St., Upper Darby, Pa. Tel: Clearbrook 9-3959
Third Wednesday, Meeting at 8:00 P.M., Bellvue Stratford Hotel.

**PITTSBURGH**
Miss Louise Suckfield, P.O. Box 2038, Pittsburgh 30, Pa. Tel: HI 1-6880
Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Roosevelt Hotel.
April 24, "Spectro-Analysis Instrumentation," Dr. B. H. Billings, Baird Associates Inc.
May 22, "The Bethlehem Flow Tube, Its Theory, Design and Development," V. Gentile, Jr., Bethlehem Fdy. & Mach Co.
Sound Slide Film No. 2 at April and No. 3 at May meeting.
**Pittsburgh Inspection & Gaging Committee.**
Second Tuesday, Meeting at 8:00 P.M., Wm. Penn Hotel. Tel: CE 1-5621
April 11, "Inspection of Ordnance Material and Material in Peace and War," S. R. Dickinson, Pgh. Ord. Dist., also Sound Slide Film No. 1.

**PRESQUE ISLE**
Edwin P. Schuwerk, 445½ Halley St., L. P., Erie, Pa. Tel: 2-3349
Fourth Tuesday, Meeting at 8:00 P.M., G. E. Community Center, East Lake Rd.
April 25, Demonstration of new illumination equipment, B. A. Thomas, G. E. Co.

**RICHLAND**
M. T. Slind, M-6, Rm. 107, Richland, Washington Tel: 4615-R
Second Wednesday, Meeting at 7:30 P.M., American Legion Hall.
May 10, Sound Slide Film No. 2.

**ROCHESTER**
R. C. Schwarz, Jr., 1201 Granite Bldg., Rochester 4, N. Y. Tel: Monroe 4610R
Fourth Tuesday, Meeting at 8:00 P.M., Univ of Rochester, Physics Lecture Hall.
May 22, Social Program

**SARNIA**
Fred T. Yorke, P. O. Box 213, Point Edward, Ontario, Canada. Tel. 2363J
Second Friday, Meeting at 8:00 P.M., Moose Hall.

**SOUTH BEND**
Sam M. Rouse, 436 Moccasin Ave., Buchanan, Mich. Tel: 678
First Thursday, Meeting at 8:00 P.M., Engineers Club, Hotel La Salle, South Bend.

**SOUTH MICHIGAN**
Larry DeHaan, 1117 Cobb Ave., Kalamazoo, Mich. Tel: 2-0385
Fourth Wednesday, Dinner at 6:30 P.M. Meeting at 8:00 P.M., Chicken Charlie's, Kalamazoo.

**SOUTH TEXAS**
H. C. Givens, La Gloria Corp., P.O. 637, Falfurrias, Texas. Tel: 122-W
First Thursday. Meeting at 7:30 P.M., Garner Aircraft Instrument School.

**ST. LOUIS**
W. G. Lee, 4710 Delor St., St. Louis 16, Mo. Tel: FL 8516
First Wednesday, Meeting at 8:00 P.M., Engineers' Club of St. Louis.
May 3, Social Program

**TENNESSEE**
N. M. Taylor, 16 Edgewood, Kingsport, Tenn. Tel: 3338J
No definite night, Dinner at 6:45 P. M., Meeting at 8:00 P.M.

**TULSA**
C. R. Horton, 8211 E. 7th, Tulsa, Oklahoma Tel: 92-1434
First Monday, Meeting at 6:45 P.M., Engineering Bldg., Tulsa Univ.

**TWIN CITIES**
Alden Hine, c/o Giesika & Pinkney, 552 Plymouth Bldg., 6th & Hennepin Ave., Minneapolis 2, Minn. Tel: Whittier 6420
Fourth Tuesday, Dinner at 6:30 P.M. Coffman Memorial Union. U. of Minn.
May 23, "Instruments in Weather Forecasting," S. F. Spilhaus, U. of Minn.

**WASHINGTON**
Raymond E. Miller, 20-224 Naval Ord. Lab., White Oak, Md. Tel: JU 7-6742
Third Monday, Meeting at 8:00 P.M., P. E. P. Co. Auditorium.

**WAYNE COUNTY**
Robert Karr, 2455 Biddle Ave., Wyandotte, Michigan. Tel: 0167J
Third Monday, Dinner at 6:30 P.M., Meeting at 8:30 P.M., Poremba Hotel, Ecorse, Mich.

**WILMINGTON**
Dean Valentine, 34 N. Hill Drive, West Chester, Pa. Tel: 0293W
Third Tuesday, Meeting at 8:00 P.M. Harlan Public School, Wilm.

# *JOURNAL* of the Southern California Meter Association

President: R. Frank Fields — Auditor: John T. H. Morris
Vice-President: James E. Adams — Past-President: J. C. Groenewegen
Secretary-Treasurer: George H. Forster, 2916 Eucalyptus Ave., Long Beach 6, Calif.


# *The* Two-rotor Type *of* Positive-displacement Liquid Meter


By PAUL RENFREW, Brodie Meter Co.


IN view of the fact that your organization has heard many papers on fluid meters of all kinds and classifications, as well as discussions on the individual classifications, it seems rather impossible to present any new and interesting data on any phase of the subject of meters or measurement. However, you permit, and even invite, manufacturers to present and discuss equipment of their particular design. Therefore, our discussion will be limited to the positive displacement meter, which is what we make. We should further confine the classification to liquid meters because there are problems incident to this class of meters not necessarily applicable to a fluid meter handling a gas.

## History of the Positive-displacement Meter

The positive-displacement meter is about one hundred years old. However, the performance expected and obtained from the positive-displacement liquid meter today is a product of the development work of the last twenty or twenty-five years. It is interesting to note that several of the original meters were designed and developed right here in California. Some of these original designs are still manufactured and marketed.

The development and use of positive-displacement meters was very slow for years. The companies starting to make this class of meter did not have the capital nor did they at that time see the potential market to justify large research expenditures. Pioneering is always expensive. Some early users had sad experiences which, of course, slowed down progress. Today, however, the positive-displacement meter has wide acceptance. Certain classes of equipment are not considered complete without a meter, as for instance gasoline and oil delivery trucks and loading racks.

## Principle of Measurement

The fundamental principle of measurement of the positive displacement meter is, of course, very simple. It is a measuring instrument which divides the volume being measured into segments, separating each segment from the flowing stream, isolating it momentarily, then returning it to the stream and, of course, counting the segments.

Fundamentally, then, this meter is a fluid motor or, rather, a liquid motor. It is a measuring instrument capable of absorbing energy from a flowing stream. The energy absorbed manifests itself as pressure drop. Not all mechanical principles usable for fluid motors make practical liquid meters. Also, very few principles which can be employed to make quite efficient positive-displacement pumps are usable at all for making a meter, because of the necessity of outside power required to produce movement of the displacement mechanism.

## Important Characteristics

Here, then, is the place to set down some of the general characteristics which should be kept in mind when considering the practicability of using a mechanical principle as a meter:

1. Simplicity is, of course, always the first consideration. The fewer the moving parts the better. Manufacturing and maintenance cost is always in direct proportion to mechanical complications.

**Fig. 1. Brodie "Model B-72" with "Brodimatic" counter. Maximum rated capacity 350 gpm. measuring light oils. Working pressure 150 psi.**

2. The mechanism should be easily understood so that, when necessary, maintenance can be effected without the necessity of special skill or training.

3. The principle should produce a mechanism with sufficient strength and rigidity to withstand the normal stresses, as well as the shock loads incident to practical everyday meter operation. (I doubt seriously whether any other instrument is required to meet the high performance standard of the positive-displacement meter and, at the same time, to withstand an equal mechanical load.)

4. It should have a good mechanical efficiency so that the unit will have a reasonable pressure drop.

5. The volumetric efficiency must, of course, produce an acceptable accuracy curve.

These characteristics must be considered collectively as well as individually. That is, they must all be in proper balance. To place too much emphasis on any single feature at the expense of another characteristic may, and frequently does, work to the disadvantage of the whole. For instance, to emphasize the strength and rigidity to a degree resulting in low mechanical and volumetric efficiency would not produce a practical meter. And, conversely, to sacrifice mechanical strength for high mechanical and volumetric efficiency might develop a structure of such short life as to be entirely impractical.

## General Specifications of "BiRotor" Line

In the light of these considerations, let us now examine the "BiRotor" meter. Suppose we begin by discussing


Presented before the Southern California Meter Association Jan. 19, 1950.


*May meeting*: Thursday the 18th, Rio Hondo Country Club, Downey, Calif. Dinner at 6:30; meeting 8 sharp.

*Features*: 1. "Temperature Measurement" by J. G. Ziegler (Taylor Instrument Co's); 2. "Methods of Orifice-meter Chart Calculation" (meter course review).

—Theron S. Cody
*Publicity Chairman*

the general design and construction. The unit you see here (Fig. 1) is our B-72 with a maximum rating of 350 gpm. when handling light oils.

This general design and construction are made in a range of sizes with maximum capacity of 60, 100, 250, 350, 550, 800 and 1300 gpm. All of these ratings are established on the basis of handling light oils.

This series is manufactured in four pressure ranges: namely, 150, 300, 600, and 1,000 psi. The unit presented here is, as you see, for 150 psi.

The case or housing of these meters is all-welded steel construction. The saddle which carries the flanges and supports the measuring unit, is a steel casting. A drawn shell is welded to this saddle. The mounting pad for supporting the counter is, of course, also a steel casting.

The complete meter is composed of five unit assemblies: (1) the housing or case; (2) the counter base plate; (3) the measuring unit; (4) adjustor; (5) counter.

This unitized construction is particularly advantageous from the maintenance standpoint. For instance, the measuring unit (see Figs. 2, 3 and 4) is a complete interchangeable assembly. The same unit is used in all four pressure ranges.

It is also obvious that internal pressures or stresses which might result in deformations in the external housing, are not reflected in the measuring unit. The cost of this safety feature is a slight additional pressure drop as compared to that of a single case meter.

The adjustor and counters are, of course, completely interchangeable between all sizes and pressures.

### Counters Available

Several different types of counters are available for these meters: (1) horizontal; (2) vertical; (3) Quantrol; (4) printing; (5) remote counters; (6) rate-of-flow indicators; (7) recording rate-of-flow indicators.

Here (Fig. 1) we have a vertical counter with large figures known as our "Brodimatic." This other meter (Fig. 2) is equipped with a horizontal type counter.

Sizes up to. and including, 550 gpm. units are available with the "Quantrol" counter. This feature permits the presetting of a definite quantity, and when the pre-set quantity has been delivered, the flow is automatically stopped.

The adjustor used on this series of meters is a variable-gear transmission. It changes the gear ratio between the measuring unit and the counter in increments of 5/100 of one percent.

### The BiRotor Measuring Unit

The measuring element of this meter is a liquid-sealed positive-displacement unit. Displacement is accomplished by two spiral fluted rotors. The measuring chambers are the spaces between the lobes of the rotors.

The rotors are not in metal-to-metal contact with one another or with the housing in which they rotate. The clearances between them depend upon the viscosity of the product being measured. They are maintained in properly-timed relationship with one another by helical gears which are totally enclosed to keep them out of the liquid stream.

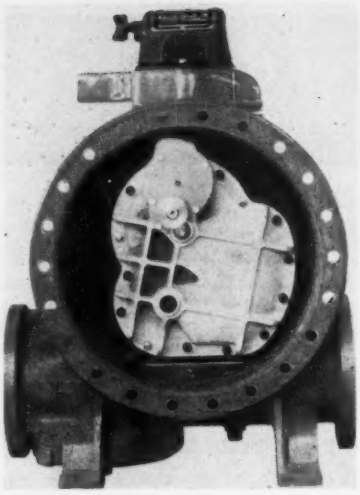

**Fig. 2. Brodie 'Model B-72" with "Series G" horizontal counter. Cover removed to show measuring unit assembly.**

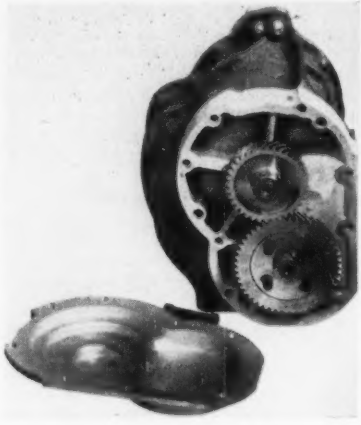

**Fig. 3. "Model B-72" measuring element with gear cover removed to show the rotor timing gears.**

Usually, the development of a practical rotary displacement mechanism, which will absorb energy from a flowing stream of liquid, results in one which is out of balance mechanically. Here, however, is a unit in which the two displacement members are in mechanical balance, both static and dynamic. This mechanical balancing results in a measuring unit with some rather novel characteristics.

There are no shock loads on the bearings or the mechanism because of the shifting of off-balance masses.

A measuring unit which is in mechanical balance is far less susceptible to damage during the period of filling the empty meter with liquid. The shock resulting from the sudden entrance of non-compressible liquid into a measuring mechanism, which is operating at or near its maximum on air or vapor, is frequently damaging to most meters.

### Factors Controlling Meter Life

We will, of course, know a great deal more about this measuring principle and mechanism in the years to come. Its performance thus far has exceeded the expectations of its designers, and, as of now, we are unable to predict just what its life expectancy will be. However, we believe we can safely say it will be much longer than the time estimated for amortization of capital equipment of this class by most companies.

The life expectancy of the positive-displacement pump, or meter, or, for that matter, any piece of liquid handling equipment, is a variable depending upon, among other things:

1. The lubricating qualities of the liquid handled.

2. The amount and particle size of abrasive matter in relation to the viscosity of the liquid handled.

Positive-displacement meters for measuring non-viscous liquids as, for instance, aviation motor fuel, are necessarily rather closely fitted mechanisms. On the other hand, a meter fitted to handle lube oil or a heavy fuel oil of 1500 or 2000 Seconds Furol could have considerably more clearance. From this, it is obvious that the latter unit would pass abrasive matter without any damage that might be disastrous to the more closely fitted unit measuring aviation gasoline.

The life expectancy is further influenced by the rate of flow and the continuity of operation. It is obvious that a meter operating at its maximum recommended rate continuously will have a shorter life than one running at half-speed intermittently.

The maximum and minimum capacity ratings of a positive-displacement meter represent the range of flows over which the meter shows acceptable performance characteristics; i.e., acceptable mechanical and volumetric efficiency. The maximum capacity is usually established on the basis of intermittent operation, and is reduced somewhat as it becomes more or less continuous operation.

Furthermore, the ratings are usually established for liquids in the viscosity range of gasoline through kerosene, automotive diesel fuel, etc. As viscosity decreases from kerosene down through high-octane, butane, propane and so forth, we recommend reduction in maximum rate at which the meter is run, this reduction being made because of lack of lubrication with these products. At the other end of the scale, we, of course, reduce the maximum rating as the viscosity increases, for the same reasons you reduce rate in a pipe line.

### Factors Controlling Accuracy

The accuracy curve of a meter, which is reflection of its volumetric efficiency, is influenced by the physical characteristics of the liquid being measured, the principal factor being viscosity. Most of the positive-displacement meters are of this liquid-sealed class. In any liquid-sealed meter, there is some slippage or

flow of liquid through the sealing clearances. For any given set of conditions, the slippage increases as the viscosity decreases and, inversely, decreases as the viscosity increases. When viscosity increases to a point where the liquid film will support the differential pressure, slippage of course ceases. The greatest change in this slippage factor occurs at viscosities below 1.5 or 2 centipoises.

From this, it is obvious that radical changes in differential pressure would also affect the slippage factor, especially when measuring a non-viscous liquid, such as a high-octane aviation gasoline. Such changes in pressure differential result from a change in either mechanical friction within the measuring mechanism, or a change in work done, counter load, packing box friction, etc.

We stated earlier that there is no contact between the rotors or between the rotors and the body in which they rotate. Furthermore, there will be no contact and therefore no change in mechanical friction as long as the bearings and gears maintain them in this relationship. Now, if there is no change in the outside load, (driving of counter, packing box friction, etc) there should be no change in accuracy.

## Application and Use of Positive-Displacement Meters

The positive-displacement meter, like any other instrument, has its proper application. There are certain jobs it will do better than any other type of meter. There are also certain jobs that only a positive-displacement meter will do properly. However, like other mechanical mechanisms, it has its limitations.

This type of measuring instrument has made a real place for itself in the operation of refinery or pipeline terminal loading racks. It provides means for operational and accounting procedure which enable plant management to control truck and transport loading. The difficulty of maintaining accurate calibration of transporting and distributing tanks is well known. Frequently meters will point out errors in tank calibration, and frequently these errors, if continued, would represent a sizeable loss. Also, overloading of such tanks is the human tendency which can also add up to large losses. A meter, properly used, eliminates this practice.

Most of the transport loadings are inter-company transactions with three interested parties. Close accuracy is not only desirable in this operation, but also necessary. To maintain the proper accuracy, there should be a standard against which the meter should be regularly checked. The standard, in this case, is a calibrated proving tank with a holding capacity not less than one minute's operation of the meter at its maximum rate of flow. It is obvious that deliveries from a regularly calibrated meter are not likely to be subject to question.

Barrel-filling and can-filling meters at the refineries or the bulk terminals

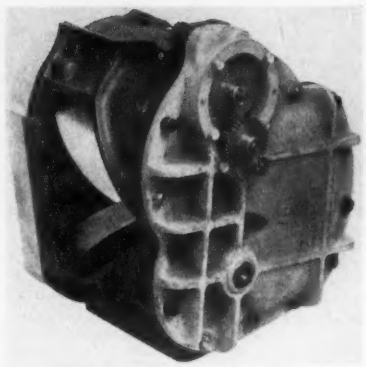

Fig. 4. "Model B-72" measuring element showing inlet port.

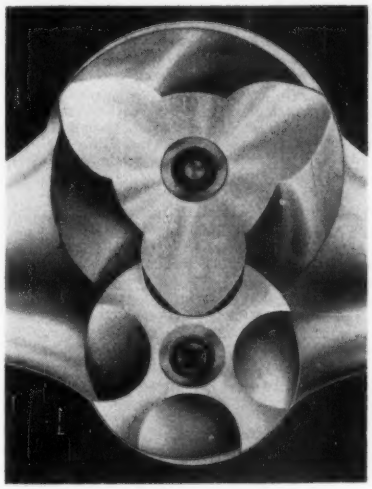

Fig. 5. Section through rotors to show measuring chamoers.

are applications to which meters are readily and economically adapted. The initial cost, as well as the installation cost, is much less than for the other accepted methods. The meter installation is more flexible in that it can be moved about as required, by changing operating conditions. The accounting and operating advantages of the standardized package are fully obtainable through the use of meters.

A good many refinery operations have corrosive problems that meters, generally speaking, are not prepared to meet. However, they are used to real advantage and economy in such installations as:

In grease compounding for measuring the oils into the grease-making unit.

In blending operations, such as asphalt, lube oils, paint thinners and solvents.

For checking inter-department movement of refined and semi-refined products.

In crude and product pipe-line operations, meters have proved economical and advantageous. At the crude oil gathering station, meters are used for measuring the oil into the station as well as measuring it from the station storage into the main line. On product lines meters are employed at the take-off terminals for measuring products into storage as well as loading transports and trucks. In these services, meters serve to reduce the storage facilities required because it is entirely possible to simultaneously pump into and out of a tank.

There are probably more meters used for checking well production in this area than in any similar area of the U.S. You are therefore fully informed on the advantages and economy resulting from their use as well as the problems incident to handling a liquid which frequently contains sand, silt and water.

## Installation, Operation and Maintenance

Satisfactory meter performance starts with the selection of the proper unit for the job. To do this intelligently, we must know: (1) the maximum and minimum rates of flow; (2) the working pressure; (3) the physical characteristics of the liquid to be metered. Remember that it is more economical to have an over-sized meter than one too small for the job.

We must next inquire whether our installation includes the necessary accessories:

1. Positive-displacement meters will measure the air or vapor contained in a liquid, as well as the liquid itself. If the liquid to be measured does contain air or vapor, air or vapor separator and eliminator are necessary if accurate measurement is to be obtained.

2. A metered installation should include a strainer, if for no other reason than to protect it against accidents such as the entry of a bolt, nut or even a wrench.

3. Frequently it is desirable and necessary to employ a meter in an installation whose capacity is several times the maximum rating of the meter. A rate-of-flow control valve should be used to protect the meter against damage from excessive speeds.

In planning the installation and your operating procedure, make provision for checking or testing the accuracy of the meter periodically. A calibrated proving tank may be justified, if exacting accuracy is required. Comparing the meter reading with the careful gaging of a stock or processing tank may be entirely satisfactory, if it is used only as a check instrument.

It is, of course, a corollary that a meter be operated within the limits as established by the manufacturer, and maintained in good operating condition, if it is to deliver acceptable accuracy and long life. I should like to emphasize that preventive maintenance is far more economical than break-down maintenance.

I believe you are already aware that A.P.I. in cooperation with the A.S.M.E. have written a code covering the installation, proving and operation of positive displacement meters. The tentative code was A. P. I. No. 1101. The final revised code was approved at the November A.P.I. meeting and should be available in the not-too-distant future.

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# Manufacturers' New Literature

In this department we report new literature pertaining to Instrumentation, received from the manufacturers. We urge readers to request ONLY those bulletins which will be of value to them. Use the Postage-free Order Card on Page 415.

S-193 HEAVY ELEMENTS CHART. Chart, 17 by 22 in., in four colors, shows radioactive transformations of the elements from 81 to 95. —W. M. Welch Mfg. Co., 1515 Sedgwick St., Chicago 10, Ill.

S-194 "THE LABORATORY." 24-page, Vol. 19, No. 3 issue of this house organ features article titled "Ion Exchangers—Quiet Revolutionists of Industry," also articles on maker's laboratory mixers, and other laboratory apparatus.—Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.

S-195 e/m APPARATUS. 2-page bulletin illustrates maker's e/m apparatus; covers features, specifications, dimensions, gives prices.—W. M. Welch Mfg. Co., 1515 Sedgwick St., Chicago 10, Ill.

S-196 TIME SWITCHES. 4-page bulletin describes and illustrates maker's "TS-50 Inter-Matic" time switches and their various contact arrangements; covers features, specifications, prices.—International Register Co., 2624 W. Washington Blvd., Chicago 12, Ill.

S-197 RECORDING CHRONOGRAPH. 8-page Bulletin 50-3 illustrates and describes maker's recording chronograph; covers uses, features, operation, calibration.—Theodore M. Long, 40 S. Bridge St., Somerville, N. J.

S-198 MULTIPLE-SIGNAL ALARMS. 4-page bulletin illustrates and describes maker's "Series 400 Panalarms" hermetically-sealed multiple-signal alarms for hazardous and corrosive atmospheres; covers operation sequence, features and applications.—Panalarm Products, Inc., 7215 N. Clark St., Chicago 26, Ill.

S-199 MAGNETIC DATA-STORAGE SYSTEMS. 8-page bulletin describes and illustrates maker's magnetic data-storage systems; covers uses, applications, characteristics.—Engineering Research Associates, Inc., 1902 W. Minnehaha Ave., St. Paul 4, Minn.

S-200 THERMOREGULATOR. 2-page bulletin illustrates and describes maker's "Quick-Set" thermoregulator; covers features, operation.—F-B Instrument Co., 2633 Trenton Ave., Philadelphia 25, Penna.

S-201 DEMONSTRATION MAGNETIC AMPLIFIER. 2-page bulletin describes and illustrates maker's demonstration magnetic amplifier for schools and industry; covers applications; lists prices.—Vickers Electric Div., 1815 Locust St., St. Louis 3, Mo.

S-202 FLOW CONTROL VALVE. 2 sheets describe and illustrate maker's "No. 235" adjustable lift-opening lever-operated control valve; covers features, applications, specifications.—Atlas Valve Co., 282 South St., Newark, N. J.

S-203 RENTAL INSTRUMENTS. 12-page catalog describes recording ammeter, voltmeter, wattmeter, current transformer available on rental basis; also includes copy of "The Graphic" Bulletin No. 839-A on Esterling-Angus recording wattmeters.—Instru-Rental Co., 411 Albee Bldg., Washington 5, D. C.

S-204 POWER SUPPLIES. 4-page bulletin describes and illustrates maker's electronically-regulated power supplies (single, twin and Klystron models); gives complete specifications.—Furst Electronics, 12 S. Jefferson St., Chicago 6, Ill.

S-205 BIOLOGICAL RESEARCH AMPLIFIER. 2-page Technical Data Letter 8-1a describes maker's "No. 8121" biological research amplifier; gives complete specifications, data.—Edin Electronics Co., 207 Main St., Worcester 8, Mass.

S-206 DIRECT-COUPLED AMPLIFIER. 2-page Technical Data Letter 8-2a describes maker's "No. 8100" direct-coupled amplifier; gives complete specifications, data.—Edin Electronics Co., 207 Main St., Worcester 8, Mass.

S-207 DIELECTRIC SEALING COMPOUND. 16-page bulletin describes and illustrates use of maker's "DC-4" non-melting waterproofing and insulating silicon compound for aircraft ignition systems, electrical control systems, and electronic equipment; covers specifications, physical, physiological and dielectric properties.—Dow Corning Corp., Midland, Mich.

S-208 HIGH-SPEED CHRONOSCOPE. 4-page bulletin illustrates and describes maker's high-speed chronoscope; covers operating principle, measurement methods, ranges; also covers maker's "Model 211" input adapter and "Model 301" photoelectric adapter; lists methods of operation, specifications for each. American Chronoscope Corp., 316 W. First St., Mount Vernon, N. Y.

S-209 "KELEFAX." 8-page Vol. 1, No. 1 issue of this house organ features article titled "Units and Dosimetry of Ionizing Radiation"; also contains table on comparison of radioisotopes, and radiation-intensity reduction-value curve; illustrates and describes several of maker's radioactivity indicating and measuring instruments.—The Kelley-Koett Instrument Div., 12 E. 6th St., Covington, Ky.

S-210 "THE GENERAL RADIO EXPERIMENTER." 8-page Vol. 24, No. 9 issue of this house organ features article titled "A New Bridge for the Measurement of Impedance between 10 and 165 Mc." on maker's "Type 1601-A" VHF bridge.—General Radio Co., 275 Massachusets Ave., Cambridge 39, Mass.

S-211 TIME-CYCLE CONTROLLER. 16-page bulletin 98154 illustrates and describes maker's "Flex-o-Timer" time-cycle controller; covers types, advantages, applications, typical installations and ordering information.—Taylor Instrument Companies, Rochester 1, N. Y.

S-212 CALIBRATION AND VIBRATION-TESTING INSTRUMENTS. 6-page bulletin No. 11 illustrates and describes maker's calibration instruments and vibration testers; covers capacities, uses.—The Calidyne Co., 751 Main St., Winchester, Mass.

S-213 POLAROGRAPHIC ANALYSIS. 104-page Bibliography of Polarographic Literature "E-90(1)" lists 2208 references on scientific papers from 1903 to middle of 1949; includes foreign and domestic sources, 1310 authors and 903 main subject classifications.—Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia 44, Penna.

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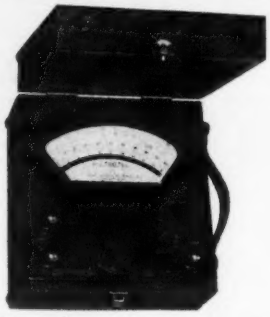

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**S-215 LIQUID-LEVEL CONTROLLERS.** 4-page bulletin C-41A describes and illustrates maker's level controllers for steam and hot water boilers; lists specifications, service recommendations, prices.—McDonnell & Miller, Inc., Wrigley Bldg., Chicago 11, Ill.

**S-216 ELECTRIC TIMERS.** 2-page Bulletin No. 7 illustrates and describes several of maker's timers and relays; covers advantages, applications.—R. W. Cramer Co., Centerbrook, Conn.

**S-217 FLOW AND TEMPERATURE PROBES.** 16-page bulletin describes and illustrates maker's high-precision research probes for measuring temperature, pressure, velocity and direction of flow in conduits, through and around an object, etc.; explains uses, gives technical data.—The Airflo Instrument Co., Glastonbury, Conn.

**S-218 ROTARY CONTROL SWITCHES.** 12-page catalog illustrates and describes maker's "Type P" rotary switches for control and transfer applications; covers specifications, advantages, circuit diagrams and dimension data.—Electro Switch Corp., 167 King Ave., Weymouth 88, Mass.

**S-219 GLASS FRACTIONATING COLUMNS.** 4-page Form 4G250FE4 pictures and lists new prices for maker's glass fractionating columns and accessories (columns, perforated bubble-plate and packing-type; column unit, concentric tube; still heads; solenoids; feeds sections; etc.).—Glass Engineering Laboratories, Belmont, Calif.

**S-220 WIRED TELEVISION.** 16-page Bulletin 1025 illustrates and describes maker's "Utiliscope" (camera, power unit, receiver) wired television for remote observation of objects, operations or conditions; covers applications, specifications, advantages.—Diamond Power Specialty Corp., Lancaster, Ohio.

**S-221 THROTTLING PNEUMATIC OPERATORS.** 8-page Technical Bulletin 104 describes and illustrates maker's pneumatic operators for throttling control service; covers design, application, principles of operation, features.—Conoflow Corp., 2100 Arch St., Philadelphia 3, Penna.

**S-222 INSTRUMENT MOUNTING BASES.** 8-page Catalog 502 illustrates and describes maker's "Barrymount" vibration isolators and mounting bases for airborne electronic equipment; covers advantages, isolation characteristics; dimensions and specifications listed for each type.—The Barry Corp., 173 Sidney St., Cambridge 39, Mass.

**S-223 ELECTRICAL INSTRUMENTS.** 14-page bulletin describes and illustrates maker's electrical laboratory instruments (Z-angle meter, r-f. Z-angle meter, r-f. oscillator, phase meter), potential dividers and components; covers complete specifications for each. Reprint, "Measuring Phase at Audio and Ultrasonic Frequencies," from "Electronics," Oct. 1949, enclosed with bulletin.—Technology Instrument Corp., Waltham, Mass.

**S-224 PHOTOELECTRIC CONTROLLERS.** 12-page Catalog 847 describes and illustrates maker's photoelectric control equipment (amplifiers, photocell receivers, burglar alarm systems, communication system); covers advantages, applacations.—Worner Electronic Devices, Rankin, Ill.

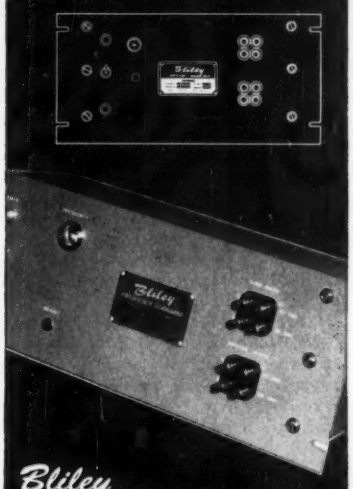
**S-225 "BIDDLE INSTRUMENT NEWS."** 4-page Vol. 6, No. 1 issue of this house organ features articles on maker's insulation testers, and department on "Questions and Answers on Insulation Testing."—James G. Biddle Co., 1316 Arch St., Philadelphia 7, Penna.

**S-226 TEMPERATURE TEST CABINETS.** 4-page bulletin illustrates and describes maker's high- and low-temperature controlled-humidity test cabinets and industrial water coolers; covers ranges, dimensions.—Standard Cabinet Co., P.O. Box 67, Rutherford, N. J.

**S-227 "SPECTROGRAPHER'S NEWSLETTER."** 4-page Vol. III, No. 4 issue of this house organ features article (continued from Nov. '49) "Spectrochemical Analysis of Copper Alloys."—Applied Research Labs, 4336 San Fernando Rd., Glendale 4, Calif.

**S-228 VACUUM-TUBE VOLTMETER.** 4-page bulletin illustrates and describes maker's "Model V-109" vacuum-tube voltmeter for TV and FM


# 2x10⁻⁷



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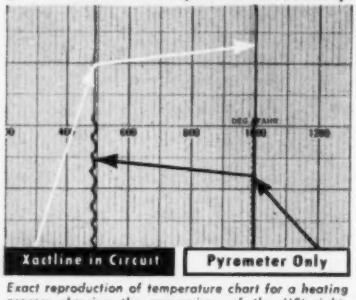


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**S-229 PROGRAM CONTROLLERS.** 2-page Bulletin CH-1 describes and illustrates maker's "Chronotrols" automatic time-temperature program controllers; lists models, features, ranges and prices.—Wheelco Instruments Co., 847 W. Harrison St., Chicago 7, Ill.

**S-230 "HASTINGS INDICATOR."** 8-page March 1950 issue of this house organ features article on maker's "Radist" hyperbolic systems, vacuum gage, and other equipment.—Hastings Instrument Co., Inc., Box 1275, Hampton, Va.

**S-231 INSTRUMENT CONTROL PANELS.** 8-page Bulletin 773 illustrates and describes maker's instrument and control panels for all sizes and types of boiler rooms; covers construction, advantages, applications.—The Hays Corp., Michigan City, Ind.

**S-232 VALVE-SIZING CHARTS.** 2-page Supplement 2, Catalog 70 contains liquid and gas valve-sizing charts, ranges 0.02 to 10,000 gpm. and 1 to 100,000 lbs. per hr.—Dep't 7007, Fischer & Porter Co., Hatboro, Penna.

**S-233 "PRECISIONOMICS."** 4-page Vol. 2, No. 1 issue of this house organ features article, "The Phenomenal Growth of Instrumentation" (abridged from editorial in ANALYTICAL CHEMISTRY), and describes maker's laboratory stirrers, mixers, etc.—Precision Scientific Co., 3737 W. Cortland St., Chicago 47, Ill.

**S-234 TACHOMETER GENERATORS, INDICATORS.** 6-page bulletin describes and illustrates maker's non-directional tachometer generators, indicators, portable electric, and electric hand tachometers; covers specifications, ranges, features.—The Electro-Mechano Co., Milwaukee, Wis.

**S-235 "THE OHMITE NEWS."** 2-page Feb. 1950 issue of this house organ features article on maker's 25th anniversary; covers maker's resistors, potential dividers, rheostats.—Ohmite Mfg. Co., 4835-41 Flournoy St., Chicago 44, Ill.

**S-236 VIBRATION ISOLATORS.** 4-page Bulletin G-102 describes and illustrates maker's vibration isolators and control materials; lists types, uses, ranges; contains chart of recommendations for 50 typical machine applications.—The Korfund Co., Inc., 48-35-J 32nd Place, Long Island City 1, N. Y.

**S-237 NETWORK SINGLE-LINE REPEATER.** 2-page bulletin illustrates and describes maker's "Type 1-A" network single-line repeater; covers operation, application.—Nestor Engineering Co., 764 Palisade Ave., Teaneck, N. J.

**S-238 "ELECTRICAL MEASUREMENTS."** 8-page revised January 1950 issue of this house organ features article on maker's "Model FM" multi-range fluxmeter; covers range, method of use, search coil design, specifications and prices.—Sensitive Research Instrument Corp., Mount Vernon, N. Y.

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S-251 **"WHEELCO COMMENTS."** 4-page Vol. 9, No. 2 issue of this house organ features articles on use of maker's recorders and controllers in manufacture of clock springs for automobile electric clocks, and other applications.—Wheelco Instruments Co., 847 W. Harrison St., Chicago 7, Ill.

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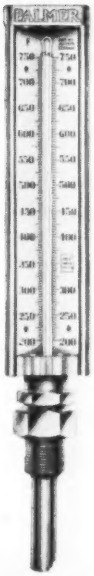


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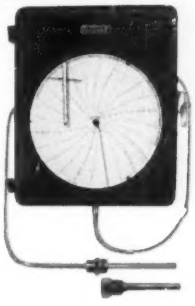

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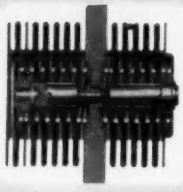

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